NESTING ECOLOGY OF COLONIAL WATERBIRDS AT BHITARKANIKA MANGROVES, ORISSA

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By

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CERTIFICATE

This is to certify that the thesis of **Mr. Gopi G.V.** entitled "**Nesting ecology of colonial waterbirds at Bhitarkanika Mangroves, Orissa**" is an original piece of work submitted to the Saurashtra University, Rajkot (Gujarat), for the award of the **Doctor of Philosophy in Wildlife Science**.

Mr. Gopi G.V. has put in more than six terms of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted for any other University or Institution.

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(Gopi.G.V)

EXECUTIVE SUMMARY

INTRODUCTION

Colonial nesting is an important feature among a majority of the members of Pelicaniformes and Ciconiiformes. The nesting colonies of these birds that represent spatial and temporal clumping of nests are popularly referred to as heronries. One of the largest heronries in India is located in the Bhitarkanika mangroves, along the east coast of India. Over 30,000 birds breed every year in this heronry, a single unbroken patch with an approximate area of less than 5 ha area comprising 3800 – 4200 trees are used for nesting. Birds use five species of mangrove trees for nesting which include *Excoecaria agallocha* (Guan), *Heritiera fomes* (Bada Sundari), *Cynometra iripa* (Singada), *Hibiscus tiliaceus* (Bania), *Tamarix troupii* (Jagula) for nesting in the heronry. . The breeding birds in this mixed species colony are Asian Openbill, Great Egret, Intermediate Egret, Little Egret, Cattle Egret, Grey Heron, Purple Heron, Black-crowned Night Heron, Little Cormorant, Darter, and Black-headed Ibis. The Asian Openbill is the most abundant species nesting in the heronry (66%) and the least abundant being the little egret (0.8%). The heronry in Bhitarkanika is located in an island covered with mangrove vegetation. The availability of large number of nest trees in terms of the mangrove forest and foraging areas in terms of the wetlands inside the forest and the paddy fields surrounding the forest are believed to be the factors favouring such large congregation of breeding water birds in the heronry. However, there exists no quantitative information on this massive heronry. Most of the birds from the nesting colony are commonly seen foraging in the paddy fields adjoining the Sanctuary. In recent years paddy fields in this area are rapidly being converted to shrimp ponds, thus reducing the foraging areas available for the breeding birds. It is therefore imperative to understand the biology of these breeding birds in the heronry and understand their resource use pattern in response to concurrent changes in the ecosystem so that proper measures can be taken to avoid any possible threat in future.

BREEDING PATTERNS

There was significant change in the nest profile during various stages. Asian Open bill, Grey heron, White ibis, Large egret, Little cormorant, Intermediate egret, Little egret showed < 50% success rate and Purple heron, Oriental darter showed > 50% success rate. Asian Openbill showed delayed Clutch Initiation Date compared to other species from Nest Initiation Date, probably due to delay in Monsoon in both years. White ibis and Little egret had the least incubation duration, Oriental darter and Asian Openbill had larger incubation duration. Night heron and Large egret had the least clutch and White ibis and Oriental darter had larger clutches. Reproductive success was not random and spatial location at the heronry was a governing factor of reproductive success, proving the well proven hypothesis that breeding success may differ between centre and edge nests in colonial breeders. Success rate is independent of their hierarchical order except Purple heron and Oriental darter which shows significant relation between hierarchical order & hatching success rate. Oriental darter and Purple heron showed negative-significance (More the clutch size, lesser the success rate) & for other species, no significance was obtained between clutch size and hatching success). Marked significance in growth rate difference was observed between Older and younger chicks, with older chicks showing better growth rate than the younger chicks.

RESOURCE PARTITIONING

It was observed that Asian Openbill stork, Large egret, Intermediate egret, little cormorant and little egret were associated more frequently than they would be expected at random. There was a significant avoidance trend between Grey heron and Purple heron, and between Oriental Darter and Asian Openbill stork. Interestingly, White Ibis was observed to nest away from most of the species within the heronry forming sub-colonies on its own. Results of our analysis on vertical alignment of nests did not support the body mass-nest height hypothesis which postulated a direct positive correlation between body weight and nest height among colonial waterbirds. There was a significant radial zonation of species in the heronry with Asian Openbill storks preferring the central portion of the heronry, whereas Oriental Darter and Grey heron nests were observed more towards the periphery of the heronry. On the other hand, nests of little egret, Purple heron and Night heron were found to have clumped distribution being restricted to select blocks of the heronry. These foretold patterns might have been responsible for reducing the interspecific aggression and thereby enhancing the interspecific resource partitioning.

FOOD HABITS AND LAND USE CHANGE AROUND HERONRY

A total of 1422 regurgitated food boluses were collected and analyzed. Food items were segregated and identified to species level. Morphometry of the food items were also recorded to determine as how birds avoid competition by choosing same prey species but in different sizes. Food preference for different species would also be determined. All birds showed major preference to fish except, Asian Openbill which fed 99.7% exclusively on apple snails (*Pila globosa*). Crabs were majorly preferred by White ibis, little cormorant. White ibis had significant proportion of prawns and shrimps in the diet. Night heron showed evidence on predating / scavenging on birds (Little egrets were found on 17 regurgitated samples). Water snakes (*Enhydris enhydris* and dog faced water snake) were preferred by purple heron followed by Night heron, grey heron and little cormorant. Insects (Mostly water beetle larvae) were largely preferred by White ibis, Little cormorant, Intermediate egret and little egret. Aquaculture farms are on a raise for the past one decade after the blue revolution all along the Indian coastal belts. Bhitarkanika is no exception and our surveys around the Bhitarkanika National Park and inside Bhitarkanika wildlife sanctuary revealed more than 672 farms dotting the periphery of the park. Direct evidence of intake and release of saline water from and to the river systems could have an impact on the fish population which is the major prey base for the nesting birds in the heronry. Food abundance was low adjoining the aquaculture farms thereby affecting the abundance of the forage base for Asian Openbill storks.

CHAPTER 1

INTRODUCTION

Many species aggregate for feeding, roosting and nesting activities, which are prevalent among water birds (Weins 1992). Why animals form breeding colonies is a major unresolved question in evolutionary biology. The topic continues to stir lively debate (Danchin & Wagner 1997; Tella et al*.,* 1998) and has been the focus of long term studies (Hoogland 1995; Brown & Brown 1986, 1987, 1988; Danchin et al., 1998). One of the principal issues has been whether colonies form due to limited breeding habitat; with animals forced into nesting aggregations at a net cost, or result from social benefits of clustering (Food finding, reduced predation; Lack 1968; Alexander 1974; Hoogland & Sherman 1976; Wittenberger 1981). The nesting patterns in birds ranges from widely spaced solitary nesters to densely packed colonies of hundreds of individuals. Colonial nesting occurs in 29 of the 129 avian families (Lack, 1968). Colonial nesting is an important feature among a majority of the members of the Pelicaniformes and Ciconiformes (Ali & Ripley 1987; Burger, 1981). The nesting colonies of these birds that represent spatial and temporal clumping of nests are popularly referred to as Heronries.

Colonial waterbirds face significant threats to the long-term stability of their populations and habitats due to such impacts as the destruction of freshwater wetlands, destruction and degradation of coastal ecosystems, depletion of the forage base in freshwater, coastal, and marine ecosystems, contaminants, sea level rise and various conflicts with human land and resource use. For some species, these threats have resulted in a decline in number. In other cases, these disturbances have resulted in colonial waterbird species becoming nuisance wildlife.

Aquatic birds that nest and roost colonially are particularly affected by local conditions and by their concentrated numbers, can themselves particularly impact both natural and human environments. At the same time, colonial behavior permits the construction of common conservation principles and similar best management actions for a suite of species. Maintaining populations of colonially-nesting aquatic birds at levels required for their long-term conservation therefore depends on inventory, monitoring, management action, and coordinated planning on a regional, national and international scale.

In addition to the benefits and challenges of their colonial behavior, these waterbirds have other characteristics in common. They appear to be useful biological indicators of the ecosystems on which they depend, including inland wetlands, coastal zones, and the oceans. Because they serve as indicators, their protection and management can be useful in conserving the landscape. As these habitats are altered, monitoring colonial waterbirds can provide important information on environmental changes. Colonial waterbirds are also symbols of their aquatic worlds. Herons, storks, pelicans and seabirds are cherished by many of the public and are often chosen as symbols of conservation movements, organizations, and locales. With their habitats being altered and populations changing, colonially-nesting aquatic birds need to persist within a changing environment.

The dependence of these species on restricted nesting and roosting sites makes the preservation and management of these specific sites critical. As feeding habitats are affected by human activities, these too must be managed to maintain their values for waterbirds. Human activities from disturbance, wetland drainage, coastal zone development, open ocean fish stock exploitation, and even the creation of artificial feeding opportunities in places as different as backyards and aquaculture facilities directly and indirectly affect these species. In a human-dominated landscape, preservation activities alone are insufficient and in many cases active management of populations, habitats, landscapes and various human activities are required. As widespread, visible, and cherished components of their landscapes, the requirements of colonial waterbirds must be considered at the landscape scale.

The mangrove forests of Bhitarkanika harbours one of the largest congregation of breeding water birds in the country and it is one of the top five largest heronries in India which hosts around 30000 birds every year. (Subramanya 1996; Chadha and Kar 1999). Eleven species of resident water birds are known to nest in this multi species nesting colony (Pandav 1996). The breeding birds in this mixed species colony are Asian Openbill stork (*Anastomus oscitans*), Large Egret (*Egretta alba*), Intermediate Egret (*Ardea intermedia*), Little Egret (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Grey Heron (*Ardea cinerea*), Purple Heron (*Ardea purpurea*), Black-crowned Night Heron (*Nycticorax nycticorax*), Little Cormorant (*Phalacrocorax niger*), Darter (*Anhinga melanogaster*), and Black-headed Ibis (*Threskiornis melanocephalus*). The endangered Lesser Adjutant Storks (*Leptoptilous javanicus*) and Painted storks (*Mycteria leucocephala*) also breed in small colonies in the Bhitarkanika National Park which has recently been identified as an Important Bird Area (IBA) of the country.

The heronry is located in an island covered with mangrove vegetation. Enhanced foraging due to the presence of abundant foraging areas in and around the heronry in terms of wetlands and agricultural fields, decreased predation due to the remoteness of the nesting site**,** are supposed to be the major factors in governing the largest congregation of waterbirds in the heronry. So far, there exists no empirical ecological data on the heronry.

Hence it was imperative to raise baseline information on the heronry by investigating the breeding biology of the nesting birds, resource exploitation in terms of nest material and food, nutrient requirements of the breeding birds, change in the land use pattern in foraging areas if any,

1.1 Study Objectives

1. To study the biology of the breeding birds in the heronry.
2. To study the resource use pattern in relation to habitat and food availability.
3. To study the impact of changes in the land use pattern around Bhitarkanika Protected Area on the heronry.

1.2 Species Account

Description of the species is in decreasing order of abundance in the Bhitarkanika heronry and is based on Ali and Ripley (1987) and del Hoyo et al. (1992).

Asian Open bill *Anastomous oscitans.* The gap between the mandibles, which is absent in chicks and juveniles, is the characteristic feature of the adults of this species. It is the smallest among the storks found in Asia and is widely distributed in India, Pakistan, Nepal (terai), and Srilanka. It feeds almost entirely on apple snail (*Pila spp*.) with occasional intake of frogs, crabs and large insects. It breeds in large mixed colonies mainly between July to September. It is a resident bird, shifting locally with water conditions.

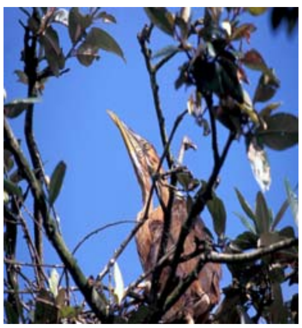
Large Egret *Egretta alba.* The species is characterized by the "S" shape of long neck and the bare facial skin (Gape line) that extends behind eye. It is found throughout the Indian sub continent, SE. Europe, W. and N. Asia to SE. Siberia, N. China, N. Japan. It generally feeds on fish, frogs, crustaceans and insects. It breeds in mixed heronries mainly between July to September. It is a resident and nomadic bird, shifting locally with water conditions.

Little Cormorant *Phalacrocorax niger.* It has few scattered white plumes on fore crown and sides of head. Generally similar to *P. pygmaeus*, but has fewer white plumes and lacks chestnut brown tone to head. It is found through the Indian subcontinent, Srilanka, Burma, Thailand, Indochina, Malaysia, and Indonesia. Feeds mainly small fresh water fish; also frogs and tadpoles. Breeds in colonies, mainly during Jun-Aug. It is a resident bird, with local movements depending on water conditions.

Intermediate Egret *Egretta intermedia.* It has well developed breast

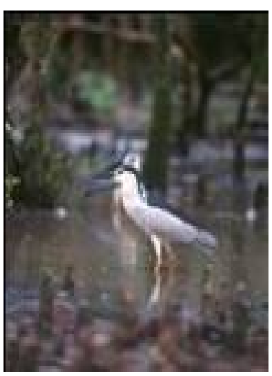
plumes. Unlike large egret the bare facial skin (Gape line) does not extend beyond the eye. It is found throughout India, Burma, Thailand, Indochinese countries, Malaysia, east to China and Japan, and the Philippines. Feeds mainly on fish, frogs, insects, and crustaceans. Occasional terrestrial prey includes grasshoppers and lizards. Breeds colonialy, mainly during Jun-Aug. It is a resident bird, shifting locally with water conditions.

Purple Heron *Ardea purpurea.* Bill in this species is proportionally longer



than in most members of *Ardea*. Purple heron is found throughout the plains of India, Pakistan, Nepal (lowlands), Sri Lanka, Burma, Thailand, the Indochinese countries, China, and Philippines. Mainly feeds on fish, frogs, aquatic insects and crustaceans. The diet also includes small birds and mammals, snakes and lizards. It is a colonial breeder. It is a resident bird, shifting locally with water conditions.

Black Crowned Night Heron *Nycticorax nycticorax*. It is a stocky grey, white



and black marsh bird of the same general effect as the Pond Heron, with a markedly stouter bill. Found throughout Indian subcontinent, also in Central and southern Europe, south to Africa, Middle East, Burma, Thailand, Malaysia, the Indochinese countries to China and Japan. Diet of this species includes fish, frogs, tadpoles, turtles, snakes, lizards, insects, spiders, crustaceans, molluscs, leeches, and bats. It is a colonial breeder and often forms pure colonies of its own. Nesting takes place mainly during June-July to September. It is a resident bird, shifting locally with water conditions.

Grey Heron *Ardea cinera.* It is a long-legged, long-necked resident marsh

bird with elongated black-streaked white feathers on breast. It is distributed all through India, Africa, and Srilanka, Pakistan, Maldives, Andaman and Nicobar Islands. Mainly feeds on fish, frogs, molluscs, crustaceans, aquatic insects, small rodents, and young birds. Usually breeds in mixed heronries of egrets, storks, cormorants, night herons during July to October.

Black Headed Ibis. *Threskiornis melanocephalus.* The species is

characterized by its naked black head and neck, and long black downwardly curved curlew-like bill. It is widely distributed throughout India, Pakistan, Nepal terai, Sri Lanka, Burma, sporadically to China and Japan. Diet includes frogs, tadpoles, snails, adults and larvae of insect and worms; also fish and crustaceans. Breeds colonially, in association with storks, herons, cormorants, and other marsh birds during June/July to October. It is a resident bird, shifting locally with water conditions.

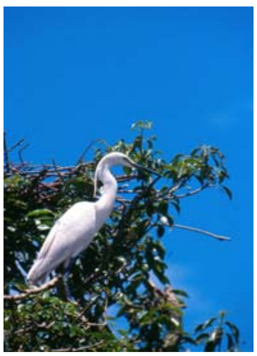
Oriental Darter *Anhinga melanogaster.* It is popularly known as snake bird.

Scapulars of this species are elongated and lanceolate. It is distributed from India to Philippines. Mainly inhabits still, shallow inland waters, less often estuaries or tidal inlets and coastal zones with mangroves and lagoons. Mainly feeds on fish, amphibians, water snakes, terrapins and aquatic invertebrates, including insects, crustaceans and molluscs. Breeds during June to October.

Cattle Egret *Bubulcus ibis*. The bird has a well developed breeding

plumage and is usually seen in attendance on grazing cattle, not necessarily near water. Distributed throughout the Indian subcontinent, Sri Lanka, Andaman & Nicobar Islands, and Maldives. Mainly feeds on insects, locusts, grasshoppers and crustaceans. Also feed on frogs, tadpoles, molluscs, fish, lizards, small birds and rodents. Breeds colonially, mainly during June-to August. It is a resident bird.

Little Egret. *Egretta garzetta.* The species is characterized by the yellow



coloration of the digits and a well developed crown feather during the breeding season. It is distributed throughout the Indian subcontinent, S. and E. Europe, N. and E Africa, Middle East, Afghanistan, Malaysia, China and Japan. Diet includes **fish**, frogs, crustaceans, water insects, etc. Breeds in mixed heronries during July to September. It is a resident bird shifting locally with water conditions.

1.3 Organization of thesis

The thesis is organized into six chapters, each chapter consisting of an introduction of the topic, elaboration of methods used, results arrived at, and discussion of the results and comparisons with earlier studies.

Chapter 1 is an introductory chapter that elaborates on all the study species, and the scope of the study.

Chapter 2 gives a descriptive account of the study area viz. the Bhitarkanika National Park

Chapter 3 reviews the information available on colonial waterbirds and refreshes current knowledge about aspects touched upon by this thesis.

Chapter 4 deals with the breeding biology of all the 11 study species within the study area.

Chapter 5 looks at the resource partitioning among the 11 study species in terms of both space and food in the study area.

Chapter 6 covers the food habits of the 11 study species in the study area and looks at the land use pattern changes adjoining the Bhitarkanika National Park and how these might affect the survival of the colonial waterbirds on a longer run.

1.4 Study justification

1. The heronry at Bhitarkanika is one of the top ten heronries in India, owing to the breeding species diversity and the number of breeding pairs (Subramanya, 1996). Unfortunately, little quantitative information is available on the breeding colony of birds at this site. Any effort to plan a long term conservation strategy needs a strong baseline data, which this study intends to generate. The data generated from this study will also help to track the extent of changes the heronry undergoes over a period of time.

2. Mangroves are one of the most threatened habitats and are subjected to various kind of biotic pressures. Mangroves are also known to be one of the most productive ecosystems, a fact that is reflected by the sheer congregation of such a large colony of water birds for breeding at Bhitarkanika. The study is the most detailed study of a heronry in a mangrove habitat. No previous study (e.g. Law 1951; Mukherjee, 1959; Chaudhury and Chakrabarty 1973; Mukhopadhyay 1980; Prasad 1992) has provided a deeper insight into the breeding of large colonial waterbirds in such a habitat.

3. Most of the birds from the nesting colony are commonly seen foraging in the paddy fields adjoining the Sanctuary. In recent years paddy fields in this area are rapidly being converted to shrimp ponds, thus reducing

the foraging areas available for the breeding birds. This study will help in answering the following questions:

a. To what an extent the species depend on various foraging habitats and utilise them?

b. Would the nesting species at Bhitarkanika suitably adopt to changes in land use patterns and continue to thrive?

c. Would the land use changes force the disappearance of certain species owing to the loss/conversion of foraging habitats that once existed?

It is therefore imperative to understand the ecology of these breeding birds in the heronry and their resource use pattern so that proper measures can be taken to avert any possible threat in future.

1.5 Research Questions

To achieve the above-mentioned aim and objectives these research questions have been put forward:

1. Is there a spatio- temporal pattern of nesting in the breeding colony? If yes, then how and why?
2. Does food and nest space availability lead to asynchronous breeding behavior, especially for conspecifics that overlap more closely in food and nesting characteristics?
3. What are the factors governing the reproductive success?

   a. Is there a density dependent impact on the reproductive success? If yes,

   b. Is there any relationship between the Central – Periphery distribution of nests on the breeding success.

   c. Does clutch size, predation, nearest neighbor distance affect hatching success?

4. Is there a differential resource selection in terms of nest location, nest materials among the birds?
    a. How does distance to the nearest neighbor distances influence nest site selection?
        - Does nearest neighbor distances differ between conspecifics and heterospecifics?
        - How densely do each species nest?
        - Does nearest neighbor distance vary between early and late season nests?
        - What is the nearest neighbor distance for predated and not predated nests?
    b. How prominent is the Vertical stratification of nests in the heronry?
    c. Do species show association/ dissociation patterns while nesting?
    d. Do nesting species show preference/ avoidance trends for certain trees?
5. Is there a spatio- temporal pattern of food abundance in and around the breeding colony? If yes, then how and why?
6. What are the effects on the food abundance due to the change in land use patterns?

CHAPTER 2
REVIEW OF LITERATURE

2.1 Heronries – An Indian Scenario

The information on heronries in India pertains mainly to a few regional studies (Mahbal 1990; Nagulu and Rao 1983; Naik et al 1991; Naik and Parasharya 1987; Parasharya and Naik 1990; Santharam and Menon 1991; Sharatchandra 1980; Singh and Sodhi 1986), several site specific studies (Chaudhuri and Chakrabarti 1973; Datta and Pal 1990, 1993; Gee 1960; Nagulu 1983; Neelakanatan 1949; Neginhal 1983; Paulraj 1984; Ragunatha 1993; Ragunatha et al 1992; Sanjay 1993; Subramanya et al 1991; Subramanya and Manu 1996; Urfi 1989c, 1990, 1992, 1993 a,b; Vijayan 1991) and a number of site records (Abdulali 1962; Ali 1960; Baker 1935; Barnes 1886, 1891; Barooah 1991; Bates and Lowther 1952; Badshah 1963; Betham 1904; Bingham 1876; Bhat et al., 1991; Bolster 1923; Chhaya 1980; Daniel 1980; Hume 1881; Jamgaonkar et al 1994; Packard 1903; Urfi 1992; Uttaman 1990 and Wilkinson 1961). Very few studies have been so far carried out on the colonial water birds of Indian mangroves. Mukerjee (1969) studied the feeding habits of few selected water birds in the mangrove forests of the sunderbans. Prasad (1992) reports about a large inaccessible heronry in the Krishna mangroves. Subramnaya (1996) updated the existing information on the status, distribution and conservation of Indian heronries.

2.2 Breeding Biology

Colonial breeding i.e., breeding among densely distributed territories that contain no resource other than nest sites (Perrins and Birkhead, 1983) is an unexplained form of social reproduction that occurs in many vertebrates. (Wittenberger et al., 1985, Brown et al., 1990). Coloniality is an evolutionary puzzle because individuals apparently pay fitness costs to breed in high densities. Identified costs are increased transmission of parasites and diseases (Moller 1987), cuckoldry (Moller et al., 1993), increased intraspecific competition for food and mates (Moller 1987), cannibalism and infanticide

(Wittenberger et al., 1985 and Moller 1987). Despite the costs, many hypotheses have been proposed to explain how colonial breeding may benefit the individual, but there is still little support for most of them and none appears compelling (Wittenberger et al., 1985 and Siegel- causey et al., 1990). Until the end of the 1980s, most discussions on how coloniality evolved were dominated by the two hypothetical advantages of enhanced food finding (Barta 1995) and reduced predation (Wittenberger et al*.,* 1985, Anderson et al*.,* 1993 and Clode 1993). By the end of that period, reviews concluded that avian coloniality is not a simple or unitary phenomenon and that not all breeding colonies are adaptive for the same reason. Recently however, new hypothesis involving habitat selection (Brown et al 1990, Shields et al*.,* 1988) and sexual selection (Mortan et al., 1990 and Wagner 1993) set the stage for a general framework in the study of coloniality.

Data from a complex of alkali lakes in central North Dakota suggest survival of piping plover eggs and chicks may be diminished at relatively high density (Mayer 1991). Reproductive success of congeneric snowy plover (*C. alexandrines*) can be reduced at high densities (Page et al., 1983). A large colony may benefit in terms of food acquisition due to increase in the number of breeding pairs that can provide information on food availability. Large colonies are believed to have a tendency to grow indefinitely. However excessive growth of a colony causes a decrease in the populations breeding rate due to intensive competition (Brown et al., 1990), mainly for nest sites (Parrish 1995).

2.3 Temporal Segregation

Custer and Osborn (1978) found asynchronous nest building phases in North Carolina. Maxwell and Kale (1977) found Florida Caerulea, started to breed later than other colony species. Frederick and callopy (1989) showed a strong difference for the nesting chronology of four species (*Casmerodius albus, Egretta tricolour, Egretta caerulea, Edocimus albus*) in florida. Maxwell and Kale (1977) and Jenni (1969) found that nests of *Egretta thula* and *Bulbulcus ibis* showed an average nest height from 2.04 – 2.59 m. Results of this work support the notion that species overlap temporally in breeding, also segregate vertically in nest placement within the colony.

2.4 Central – Periphery Distribution of Nests

Breeding success may differ between centre and edge nests (Coulson 1968, Balda and Bateman 1972; Brown and Brown 1987), but it is not always attributable to predation (Coulson 1968; Bunin and Bates 1994). Nest defense against potential predators has long been suggested as an important force in the evolution of coloniality in birds (Lack 1968; Gotmark and Anderson 1984). Nests located in the more densely populated areas of the colonies are more sheltered from predation more than those at the periphery (Wittenberger and Hunt 1985). In the context of the relationship nest density and predation, the central – periphery distribution hypothesis was first proposed by Coulson (1968) in his study of colony of Kittiwakes (*Rissa tridactyla*), where he found birds breeding in the central area were of better quality and had higher reproductive success than those nesting in the periphery. Moreover subsequent studies showed that this population is regulated by the availability of central sites (Porter and Coulson 1987) and that birds breeding in the centre have a higher survival rate (Aebischer and Coulson 1990). The variation in survival arises because central individuals are less accessible to predators (Hamilton 1971; Vine 1971). Central – Periphery distribution hypothesis is generally an accepted explanation for nest dispersion patterns in sea bird colonies (Wittenberger and Hunt 1985; Furness and Monaghan 1987; Kharitonov and Sigel- Causey 1988). However there are some examples where this hypothesis is not fulfilled. Ryder and Ryder (1981) found a colony of ring billed gulls (*Larus delawarensis*) in which there was no variation in reproductive success between central and peripheral areas, while in another colony, Pugesek and Diem (1983) observed that reproductive success were determined by different spatial distribution of age groups. Scolaro et al (1996), in a study on a colony of the South American tern (*Sterna hirundinacea*), found that birds nest site selection is at first random and then uniform but not in the central – periphery pattern. In a study on behavior of Kittiwake recruits in a colony in North shields, Porter (1990) found that first time breeders prefer more densely populated sites, with poorer quality birds being restricted to peripheral zones. Danchin et al., (1991) reported that recruits are directly attracted by successful sites and they visit these sites during the prospecting season. It's widely assumed that edge or fringe nesters should have a lower breeding success compared to central nesters (Wittenberger and Hunt 1985). Several authors have reported that edge or fringe nesters show higher levels of failure than more central nesters and that the centre advantage increases as colony size increases (Rukk 1968; Brown and Brown 1987; Spear 1983). Furthermore, several studies have shown preference by males for establishing territories with in the centre of colonies (Kittiwake, *Rissa tridactyla*, Coulson 1964; Least terns, Burger 1988).

2.5 Hatching Asynchrony

Asynchronous hatching is known to occur commonly in many birds that mainly exploit unpredictable and seasonally and/or yearly changeable food resources for example, diurnal raptors, owls, storks, herons, swifts and crows (Lack 1954, 1966). Hatching asynchrony, a widespread trait in birds (Clark & Wilson 1981; Stoleson & Beisinger 1995), promotes the establishment of intrabrood size hierarchies (Stockland & Amundsen 1988; Vinuela 1996) that may have an adaptive value; when food availability is not sufficient to raise all brood members, the smaller last hatched chicks will starve quickly, while the larger siblings may survive (Brood reduction hypothesis, Lack 1954). If these size hierarchies did not exist, more chicks per brood would die. However, few studies have successfully tested the brood reduction hypothesis (Magrath 1989; Hebert 1993) and brood reduction has been proposed to be at least partially, a non-adaptive consequence of hatching asynchrony that might be maintained for other reasons (Amundsen & Slagsvold 1991a). As many as 18 other hypothesis have been proposed to explain asynchronous hatching (Stoleson & Beisinger 1995; Slagsvold 1986). Hatching asynchrony could be an adaptive trait maximizing breeding success due to the establishment of a size hierarchy, or the pattern of incubation initiation per se could be selectively favored, rather than the consequent size hierarchy (Stolson & Beisinger

1995). For example, hatching asynchrony may be a consequence of birds starting incubation before the end of laying to avoid loss of viability of first laid eggs (“Egg viability hypothesis” Arnold et al., 1987; Veiga 1992). That loss of viability may be determined by the thermal conditions to which the eggs are exposed before incubation starts (Webb 1987). Today, most studies have tested the brood reduction hypothesis, while the possible selective forces affecting the onset of incubation have rarely been considered (Clark & Wilson 1981; Amundsen & Slagsvold 1991a; Stolson & Beissinger 1995). There is however, increasing awareness that a single hypothesis cannot explain inter or intraspecific variation in hatching asynchrony (Clark & Wilson 1981; Stoleson & Beisinger 1995; Vinuela & Carrascal 1999). Hatching asynchrony could be facultatively manipulated according to food availability, when this can be predicted at the time of laying (Increasing or decreasing hatching asynchrony when food availability is low or higher respectively, Wiebe & Borolotti 1994a).

2.6 Differential Resource Selection

Factors commonly identified to explain aggregations are the spatial availability of food and defense against predators (Emlen & Demong 1975; Birkhead & Furness 1985; Brown, Stutchaburuy & Walsh 1990). Other studies suggest that ectoparasitism and abiotic factors (Ex. Precipitation) affect habitat quality and become a dominant force influencing aggregation behaviour in birds (Hill and Levin 1989; Boulinger & Gavin 1989; Weins 1992; Bouliner & Lemel 1996). Differential resource selection is one of the principal factors, which permit species coexistence (Schoner 1974; Rosenzwig 1981). In studies of niche partitioning, nest location has received much less attention than food or habitat, perhaps because suitable nest sites are presumed to be readily available for most species. However, when a species has specific nesting requirements, suitable nesting locations may be difficult to obtain (Weins 1989; Burger & Gochfield 1990). This may bring about the overlap of nest sites and consequently, predation costs for breeders because of the attraction of the predators due to the increase in cumulative nest density (Martin 1996). The response of wild populations to their resources is not always predictable because of the outcome of the number of interacting factors, which may go since a single until multiple factors (Parish 1995). Food scarcity often leads to foraging in distant areas, which may result in formation of small colonies (Arengo & Baldasare 1995). Strong seasonal peaks in food resources may limit breeding to a single season of the year and cause synchronized breeding of the population. In these cases large colonies are formed and intense competition occurs for food (Emlen and Demong 1975). Competition might be lessened by a strategy of fine scale temporal and spatial segregation in the use of habitats among species with similar feeding habits. (Murray 1971; Hill and Levin 1989). Anderson et al., 1979, suggested vertical stratification is believed to partition resources and thereby reduce competition among co-existing species.

2.7 Habitat selection and Nesting association

The environment of most animal species is heterogeneous at different spatial and temporal scales for various characteristics that can directly affect components of fitness. The process of habitat selection is thus likely to be under strong selective pressures (Cody 1985; Martin 1993). Animals can use variety of physical cues to assess environmental suitability (Buckley and Buckley 1980; Cody 1985, Danchin and Wagner 1997). More parsimoniously, they can use some integrative cue such as the presence and activities of conspecifics (Keister 1979, Shields et al., 1988; Stamps 1991; Boulinier and Danchin 1997). Gulls and Terns breed colonially due to similar habitat preferences, mutual advantages provided by better predator avoidance, and the possibility of exchange of information for food acquisition (Erwin 1979; Burger & Gochfield 1990b; Oro 1996; Rolland et al., 1998). On the other hand, colonial birds may compete for resources, and colonies may attract predators (Wittenberer & Hunt 1985; Krebs & Davies 1987; Siegel – Causey & Kharitonov 1990). Multiple factors drive colony site dynamics in waterbirds, depending on habitat quality (Kharitonov and Siegel – Causey 1988, Fasola & Alieri 1992, Boulinier and Lemel 1996, Erwin et al., 1998). Habitat composition around nesting sites has been so far the most studied of those across (Fasola & Alieri 1992, Baxter & Fairweather 1998). Since reproduction is a time of high energy demand (Drent & Dann 1980), availability of suitable foraging sites will directly influence colony location, colony size and reproductive parameters.

2.8 Land use change, agriculture, wetlands and waterbirds

Wetlands provide a range of services to humans and the ecosystem, and ironically, their value increases as a function of their utility to humans and/ or rarity in the landscape, but declines at some point when population effects such as pollution etc. and functional value of the wetlands reduces (Mitsch and Gosselink 2000). In relation to other ecosystems, Costanza et al. (1997) estimated that wetlands are 75% more valuable than lakes and rivers, 15 times more valuable than forests and 64 times more valuable than grasslands and rangelands (estimated unit value ha^{-1} yr^{-1} for wetlands is $14,785). Economic analysis showed that in at least one example, for freshwater wetlands, total economic values exceeded values of cultivation fields that were created by draining by 60% (US$8,800 compared to US$ 3,700; Balmford et al. 2002). This information, however, has done little to curtail wetland deterioration. Agro-ecosystems are often part of the main ecosystems in which bird species accomplish all or part of their life cycles (Fuller et al., 1995, Pain & Dixon 1997; Perkins et al., 2000). Rice fields are among the most widespread of these human made habitats totaling 11% of earth's farmlands. Having replaced many natural wetlands on all continents, rice fields have become the only wetlands available for waterbirds in some regions (Fasola & Ruiz 1997). Examining how those artificial wetlands contribute to their ecology, is therefore essential to understand the population dynamics and distribution of colonial waterbirds. (Hafner & Fasola 1992; Fasola & Alieri 1992; Fasola & Ruiz 1997; Tourneq et al., 2001). It is also important from a conservation perspective because management decisions and policies require identification of species needs and the process affecting those needs (Bennetts et al., 1998).

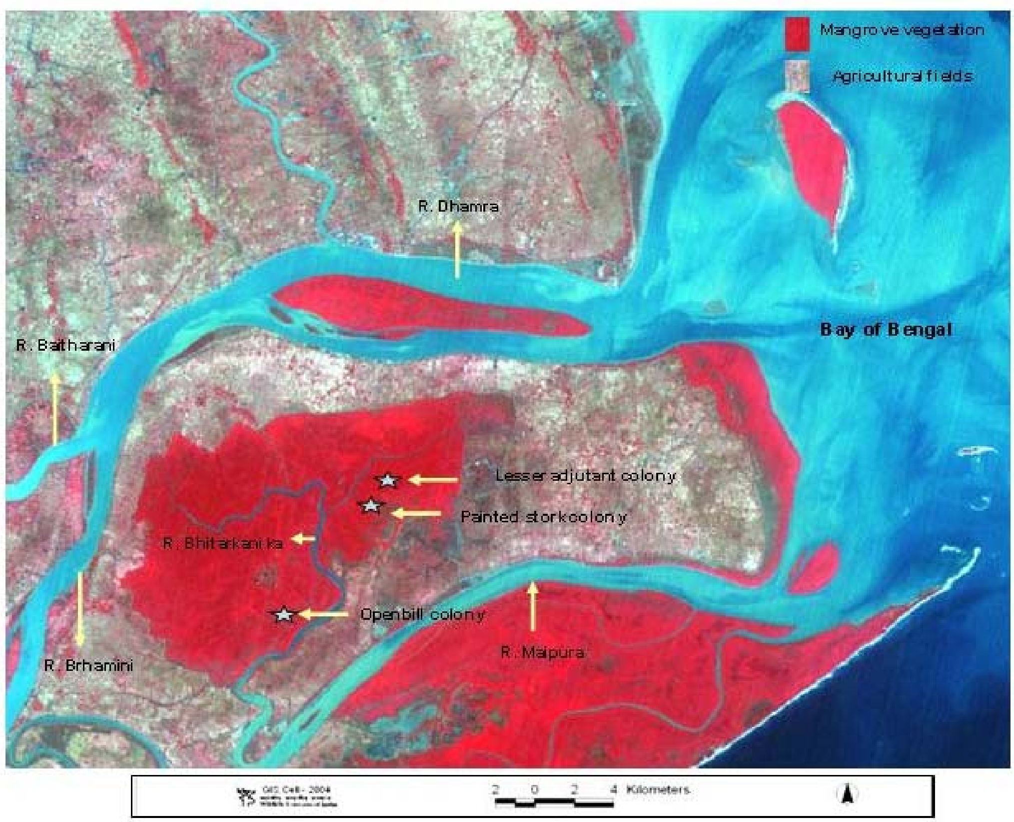
In areas with intensive transformation of landscapes where conservation of natural attributes is proving difficult, there is an increased focus on the benefits of particular crop types to birds. In the Mediterranean region and Japan, for example, development activities have resulted in the near-complete removal of small natural wetlands from the landscape. However, studies have demonstrated that with proper application of techniques, it may be possible to sustain water birds even in these areas (Elphick and Oring 2003). Of specific interest have been flooded rice paddy fields, and work in these habitats is proving that they can be of considerable importance for species that either continue to forage in them (Fasola and Ruíz 1996; Lane and Fujioka 1998), or become reliant on them (Elphick and Oring 1998; Shimada 2002). Flooded fields may continue to sustain species that are not wetland-specialists, as they can functionally resemble natural wetland habitats to an extent (Elphick 2003). Such studies are rare or entirely absent on Indian avifauna as most avifauna studies have been conducted in protected landscapes. Very little information is available on the effect of changing wetland habitats to agriculture areas on bird behaviour and ecology, and very little is published on the ecology of birds living in agricultural landscapes.

CHAPTER 3

STUDY AREA

The field study on the Bhitarkanika heronry was conducted in the Bhitarkanika Wildlife Sanctuary, Orissa. Bhitarkanika mangroves, located on the east coast of India (between 20°04'-20°08'N and 86°45'-87°50'E) represent one of the finest remaining patches of mangrove forests in India. (Map 3.1). The general elevation above mean sea level is between 1.5 to 2 meters. Higher ground extends to 3-4 meters. The field study in Bhitarkanika commenced in March 2004.

Map 3.1. Map of Bhitarkanika Wildlife Sanctuary and location of the heronry inside the National Park



3.1 Location

The Bhitarkanika Mangroves are located in the deltaic region of Brahmani and Baitarani rivers in the Kendrapara district of Orissa. The Bhitarkanika Wildlife sanctuary is situated near the former port, Chandabali, which is about 50 km from the Bhadrakh railway station. The sanctuary is bounded by rivers Dhamara to the north, Maipura to the south, Brahmani to the west and the Bay of Bengal in the east. The 35 km coast line from the mouth of river Maipura till Barunei forms the eastern boundary of the sanctuary. The annual rainfall ranges from 920 to 3000 mm.

3.2 The Bhitarkanika heronry

This is the one of the oldest and largest mixed species colony in India (Subramanaya 1996). Over 30,000 birds breed every year in this heronry, a single unbroken patch with an approximate area of less than 5 ha area comprising 3800 – 4200 trees are used for nesting. Birds use five species of mangrove trees for nesting which include *Excoecaria agallocha* (Guan), *Heritiera fomes* (Bada Sundari), *Cynometra iripa* (Singada), *Hibiscus tiliaceus* (Bania), *Tamarix troupii* (Jagula) for nesting in the heronry. The breeding birds in this mixed species colony are Asian openbill stork, Great Egret, Intermediate Egret, Little Egret, Cattle Egret, Grey Heron, Purple Heron, Black-crowned Night Heron, Little Cormorant, Darter, and Black-headed Ibis. The Asian Openbill is the most abundant species nesting in the heronry (66%) and the least abundant being the little egret (0.8%). Abundant food resources in and around the heronry and the minimal disturbance due to the remoteness of the area are speculated to be the principal factors for this large congregation of breeding birds.

3.3. Physical features

(e.g. geology, geomorphology; origins - natural or artificial; hydrology; soil type; water quality; water depth water permanence; fluctuations in water level; tidal variations; catchment area; downstream area; climate). The Bhitarkanika mangroves are in the deltaic region of Brahmani and Baitarani River in the state of Orissa along the Bay of Bengal of which the most protected and representative area is the Bhitarkanika Wildlife Sanctuary. The natural boundaries of the sanctuary are rivers and the Bay of Bengal. The sanctuary is bounded by rivers Dhamara to the north, Maipura to the south, Brahmani to the west and the Bay of Bengal in the east. The 35 km coast line from the mouth of river Maipura till Barunei forms the eastern boundary of the sanctuary. The rivers Baitarani and Brahmani after meeting together near Dangamal flow into the Bay of Bengal at Palmyra point under the name of Dhamra estuary. The river Pathsala, a tributary of river Brahmani produces two main distributaries, Kanika and Baunsagarha, and enters the sea to form the Maipura estuary in the north east part of Kendrapara district. The estuarine region of Bhitarkanika can be divided into two parts: an outer funnel shaped region known as estuarine zone and a narrow inner region known as inner estuary or river part. The habitats of the two parts are distinctly separated with the changing effect of interacting environmental factors and degree of protection from the Bay. The sanctuary is interspersed with numerous rivers, creeks and creek lets. The area is influenced by heavy alluvial silt brought down by the rivers and deposited in the deltaic areas due to regular tidal inundation. The entire area is further influenced by high detritus content of the tidal material resulting from fallen mangrove leaves. The soil is clayey loam with sand, overlaid by rich humus layer. The mosaic of rivers and creeks are influenced twice daily both by high and low tides at approximately six hours interval. The tidal level varies from the outer estuarine part towards the inland areas according to lunar cycle and is also subjected to wide seasonal variation. The climate of the area is tropical. In general there are three main seasons prevalent in this region. Summer begins from February and extends up to June. The rainy season usually starts in June and extends up to October. November to January is the winter season. The annual rainfall ranges from 920 to 3000 mm. and the main rainy months are August and September. In winter the temperature dips down to 10° C minimum and in summer the maximum temperature reaches up to 40° C. Wind velocity becomes 40 km per hour during the monsoon which ranges between 15 and 25 km per hour in winter. The area is prone to severe cyclonic storms twice almost every year during April to May and October to

November and also, there are occasional tidal bores. The humidity of the area varies between 35 to 95%.

3.4 Hydrological values

(groundwater recharge, flood control, sediment trapping, stabilization, etc.) The Bhitarkanika mangroves along the north eastern coast of India plays a key protecting the area and the human habitation adjoining it from devastating cyclones surges. The dense mangrove forests along the coast slows down the force of tidal thereby protecting life of millions of coastal inhabitants. Mangroves help in accretion. They stabilize newly formed mud and silt deposits near river mouth. Mangrove restricts and slows down erosion process on tidal river banks. The trees well equipped deep root system, pneumatophores, knee and stilt roots reduce the high wave and tidal action. Mangroves have also been useful in treating effluent, as the plants absorb nitrates and phosphates thereby preventing contamination of near shore waters.

3.5 Ecological features

The Bhitarkanika mangroves comprise of a wide variety of habitats ranging from the tidal rivers and creek to riverine islands, coastal wetlands and inter tidal zones. The low lying mangrove forests of Bhitarkanika are subjected to regular tidal inundation twice daily. Bhitarkanika has a wide network of tidal rivers and creeks. The riverine islands within the mangrove reserve are favourite roosting sites of wintering water fowls. The coastal wetlands along the eastern boundary hosts a large number of migratory water fowl during winter. These are open wetlands and are influenced by monsoon rain and regular tidal inundation. The intertidal zones near mouth of rivers Maipura and Dhamra hosts a wide variety of residents as well as migratory wading birds. The vegetation of Bhitarkanika is broadly classified into (i) mangrove formation and (ii) salt bush formation (Choudhury 1990). The salt bush formation is found along the littoral tract of Satbhaya and Gahirmatha sea shore where the soil is sandy and is not subjected to inundation. The coastline here is characterized by sand dunes reaching upto 70 - 80 ft high. Principal vegetation on these dunes includes *Ipomea pescaprae*, *Hydrophylax maritima*, *Spinifex littoreus*, *Launaea sarmentosa* and *Gisekia pharnaceoides*. Notable vegetation on these sand dunes are the extensive Casuarina plantation. Mangrove formation in the sanctuary has been classified into two categories: (1) vegetation of the estuarine bank and (2) vegetation of the inner estuarine bank (Banerjee and Rao 1990). The outer estuarine bank vegetation is found near the mouth of Dhamara and Maipura rivers. Plants in the outer estuarine region are subjected to high salinity and wave action. *Avicennia marina*, about 10 m tall with compact crown is very common and characteristically forms a pioneer tree stand along the lower inter tidal zone of estuarine bank. *Sonneratia griffithii* with widest trunk is found at low gradient mud flats along the lower inter tidal zone in mixed association with *Avicennia alba*, *Bruguiera parviflora*, *B.cylindrica* and *Aegialitis rotundifolia*. These species with increased water storage mechanism in their leaves tolerate high saline conditions and are found more commonly along the central part of the funnel shaped estuarine bank. *Sonneratia griffithii* and *Sonneratia alba* form the top canopy in this area. The second canopy is formed by *Avicennia alba*, *Lumintzera racemosa*, *Ceriops tagal* and *Bruguiera cylindrica* and the third canopy is formed by *Aegialitis rotundifolia*, *Bruguiera parviflora* and *Phoenix paludosa* (Banerjee and Rao 1990). The inner estuarine bank is strongly dissected by several creeks and creek lets. The force of the sea surf is broken due to the presence of several creeks and the vegetation here is subjected to moderate salinity. These conditions make a favourable habitat for many mangrove species and the flora is rich and diversified in this region. The dominant mangrove species in this region are *Avicennia officinalis*, *Sonneratia apetala*, *Excoecaria agallocha*, *Heritiera fomes*, *Heritiera littoralis*, *Kandelia kandel*, *Xylocarpus granatum*, *X. molucensis*, *X. mekongenesis*, *Rhizophora mucronata*, *R. apiculata*, *Aegiceras corniculatum*, *Merope angulata* and *Cerbera manghas*. Pure fomations of many of these tree species occur in the inner estuarine bank

3.6 Flora

58 species of mangroves have so far been recorded in India of which 55 are found in Bhitarkanika (Bannerjee and Rao 1990). Compared to the Sunderbans, India's largest tract of mangrove forest, Bhitarkanika represents a wide diversity of mangrove flora. The *Heritiera* formation of Champion and Seth (Type 4B/TS-4, 1968) comprising the brackish water association of *Heritiera, Cynometra, Aglaia, Cerbera*, and *Intsia* is not found in the present Sunderbans of Indian territory but are well represented in Bhitarkanika. *Rhizophora stylosa, Sonneratia griffithii* and *Heritiera littoralis* have been recorded new for Indian mangroves from Bhitarkanika (Bannerjee and Rao 1990). This association is unique only to Bhitarkanika mangroves. In Bhitarkanika a variety of wild rice (*Potresia coarctata*) grows abundantly in tidal mud flats. Based on the genetic strain of this wild rice several saline and flood resistant varieties of rice have been developed. This has led to a tremendous economic impact making it very important.

3.7 Fauna

Bhitarkanika harbours one of the largest populations of endangered saltwater crocodile (*Crocodylus porosus*) in India and is globally unique in that 10% of the adults exceed 6 m length. Nearly 1500 saltwater crocodiles inhabit the rivers and creeks of Bhitarkanika today (Kar and Pattnaik 1999, Gopi and Pandav 2009). The eastern boundary of Bhitarknika supports the largest nesting ground of the endangered olive ridley sea turtle in the world (Bustard, 1976). Nearly half a million olive ridleys on an avereage nest every year along the Gahirmatha coast of Bhitarkanika (Dash and Kar 1990). The water monitor lizard (*Varanus salvator*) otherwise rare in most part of India, commonly occurs here. Besides water monitor, two other species namely common (*V. bengalensis*) and yellow (*V.flavescens*) monitors are also sympatric here (Biswas and Kar 1981). Notable among other reptiles of Bhitarkanika are king cobra (*Ophiophagus hannah*), Burmese python (*Python molurus bivittatus*), banded krait (*Bungarus fasciatus*), common krait (*Bungarus caeruleus*) and golden tree snake (*Chrysopelia ornata*). Extremely high congregations of migratiory waterfowls are observed in the coastal wetlands around Satbhaya village and in the Bhitarkanika forest block of the Sanctuary during December and January. The mangrove forests of Bhitarkanika harbours one of the largest congregations of breeding water birds in the country (Subramanya 1996). Eleven species of Ciconiiformes are known to nest in this multi species nesting colony (Pandav 1997). The breeding birds in this mixed species colony are Asian Openbill (*Anastomus oscitans*), Great Egret (*Casmerodius albus*), Intermediate Egret (*Mesophoyx intermedia*), Little Egret (*Egretta garzetta*), Cattle Egret (*Bubulcus ibis*), Grey Heron (*Ardea cinerea*), Purple Heron (*Ardea purpurea*), Black-crowned Night Heron (*Nycticorax nycticorax*), Little Cormorant (*Phalacrocorax niger*), Darter (*Anhinga melanogaster*), and Blackheaded Ibis (*Threskiornis melanocephalus*). The endangered Lesser Adjutant Stork (*Leptoptilous javanicus*) also breeds in Bhitarkanika. Seven species of kingfishers, Black-capped (*Halcyon pileata*), White-breasted (*H. smirnensis*), Brownwinged (*H. amauroptera*), Collared (*Todiramphus chloris*) Common (*Alcedo atthis*), Stork-billed (*Pelargopsis capensis*) and Pied (*Ceryle rudis*) are sympatric here. Bhitarkanika Wildlife Sanctuary has recently been identified as an important bird area (IBA) of the country. Bhitarkanika is also home for several mammals. Five species of marine dolphins have been recorded from the area. The commonest species encountered in this area is the Indo-pacific humpbacked dolphin (*Sousa chinensis*). The other four species of marine dolphins that are found in the coastal waters off Gahirmatha are Irrawady dolphin (*Orcaella brevirostris*), Pantropical spotted dolphin (*Stenella attenuate*), Common dolphin (*Delphinus delphis*) and Finless black porpoise (*Neophocaena phocaenoides*). Notable among the other mammalian fauna of Bhitarkanika are Striped Hyena (*Hyaena hyaena*), Fishing cat (*Felis viverrina*), Jungle cat (*Felis chaus*), Smooth-coated otter (*Lutra perspiciliata*), Common palm civet (*Paradoxurus hermaphroditus*), Small Indian civet (*Vivericula indica*), Indian Porcupine (*Hystrix indica*), Wild boar (*Sus scrofa*), Spotted deer (*Cervus axis*) and Sambar (*Cervus unicolor*). The Bhitarkanika mangroves also harbour ecologically significant biodiversity and was recently found to be an important habitat for the endangered horseshoe crab (Dutta, 2007)

3.8 Social and cultural values

Mangrove ecosystems have traditionally been sustainably managed by local populations for the production of food, medicines, tanins, fuel wood and construction materials. Most of the villagers living around Bhitarkanika derive benefits from the mangrove forests in one way or the other. The entire fishing industry in the area that provides employment to local communities is dependent on the rivers and the coastal waters adjoining the mangrove forests. Some of the commercially important fishes found in Bhitarkanika are *Hilsa illisha*, *Lates calcarifer*, *Mystus gulio* and *Mullet* sp. The area is also an important source of prawn such as *Penaeus indicus* and *Penaeus monodon*. The mangrove forests of Bhitarkanika are an important source of honey. Nearly 3,000 to 5,000 kg of honey is collected from Bhitarkanika every year during February to May (Chadha and Kar 1990). A local community in this region known as 'Dalei' is specialised honey collectors and has been collecting honey for generations. Several plant species found in Bhitarkanika also provide direct employment to local communities. *Myriostachia wightiana*, a species of grass (locally known as Nalia) growing in the tidal banks and *Flagellaria indica*, a climber (locally known as Bahumurga) growing inside the mangrove forest are used for basket and rope making. Co-operative societies have been established in surrounding villages to market these products. *Phoenix paludosa*, a species of the family Palmaceae grows abundantly in Bhitarkanika. The shoot and leaves of Phoenix are widely used in the area for thatching purpose. Bhitarkanika mangroves harbour wild strains of Paddy, which is tolerant of long duration saline inundation and has significant genetic research value for the staple rice-eating community of east coast of India.

3.9 Avifaunal Research in Bhitarkanika

Notes on the avifauna of Bhitarkanika mangroves occur at random through the literature but an initial checklist list of the birds of Bhitarkanika was attempted in early nineties by Dani and Kar (1992) and then Pandav (1996) published a check list on the birds of the Bhitarkanika mangroves. He listed a total of 169 bird species to occur in Bhitarkanika, Some other studies include Nayak 2003 and Nayak 2005, who described about the ecology of resident birds in the heronry and he also made an endeavor to report about the seasonality and occurrence of Kingfishers harboring the mangroves. Kalpana (2005) has recently reported about the occurrence of Red-winged Crested Cuckoo in Bhitarkanika. Recently a total of 263 birds were added to the existing checklist of Birds of Bhitarkanika by Gopi and Pandav (2007). Gopi et al., (2006) reported about the large congregation of Indian skimmers (*Rynchops albicollis*) in the Bhitarkanika Wildlife Sanctuary. Gopi and Pandav (2006) reported about the White-bellied Sea-Eagle *Haliaeetus leucogaster* preying on salt-water crocodile *Crocodylus porosus* hatchling. Gopi and Pandav (2007) recorded breeding biology observations on Lesser Adjutant-Stork *Leptoptilos javanicus*, Asian Openbill-Stork (*Anastomus oscitans*) and Painted Storks (*Mycteria leucocephala)* in the Bhitarkanika mangroves.

Plate no. 1 Bhitarkanika heronry is one of India’s largest mixed species heronry with over 30000 birds breeding in this mall patch of < 5 ha area (Photo © Gopi.G.V)

Plate no. 2 Breeding birds use 4 mangrove trees to nest in Bhitarkanika heronry (Photo © Gopi.G.V)

Excoecaria agallocha

Heritiera fomes

Hibiscus tilliaceaus

Cynometra Iripa

CHAPTER 4

BREEDING BIOLOGY

4.1 Introduction

Information available in the ornithological literature about breeding biology of colonial waterbirds of India particularly the members of Pelicnaniformes and Ciconiiformes is fragmentary at best. There exist wide information gaps for many common and threatened species. For nearly all the species, among the more crucial unresolved questions related to breeding biology are those concerned with ecological constraints on reproductive success. Particularly desirable is to determine limits of their ability to accommodate to changing environmental conditions. Such studies are required to provide basic understanding of the colonial waterbirds adaptive strategies required for their conservation. An often asked research question while studying the breeding ecology of a species is to know, what is the reproductive success of a colonial nesting bird? Many values for clutch size, nesting success, and nesting mortality are critical site specific information required for the conservation of colonial waterbirds. Considerable attention has been focused on the reproductive success of the colonial waterbirds in the wake of discovery that most species are vulnerable to pesticide-induced eggshell thinning and egg loss during incubation (Vermeer and Reynolds 1970; Faber et al. 1972; Pratt 1972; Ohlendorf et al. 1978, 1979; Blus et al. 1971; Findholt 1981; Mitchell 1981; Bayer 1982; LaPorte 1982; Custer et al. 1983).

Colonial breeding in birds is a common yet poorly understood phenomenon. A colony may be defined as a group of animals that nest at a centralized location, from which they recurrently depart in search of food (Wittenberger and Hunt 1985). Colonial breeding may enhance foraging (Crook 1965; Emlen 1971; Fisher 1854; Lack 1968; Ward and Zahavi 1973), reduce the probability of predation (Burton and Thurston 1959; Kruuk 1964; Horn 1968; Burger

1987; Hoogland and Sherman 1976), or result from resource constraints (e.g. nest sites, food distribution) (Horn 1968; Lack 1968).

4.1.1 Hatching Asynchrony: Colonially nesting waterbirds like storks and ardeid species typically begin incubation prior to the completion of laying, which results in Asynchronous hatching (Owen 1960; Osawa 1968; Blaker 1969; Schuz 1943, 1957). Asynchronous hatching has been reported in many other avian species like storks (Schuz 1943, 1957), raptors (Shmaus 1938), owls (Watson 1957), Crows (Lockie 1955) and swifts (Lack 1956). Lack (1954, 1966) considered asynchronous hatching to be a mechanism that allows brood size to be reduced to the number that parents can raise successfully, depending on food availability. Several studies have demonstrated reduced post-fledging survival of individuals according to their hatching rank order (Husby 1986; Spear and Nur 1994; Horak 1995; Slagsvold et al. 1995; Hafner et al. 1998). Because of their size superiority and sometimes sibling aggression (Inoue 1985), senior siblings obtain more than their proportionate share of the total food and, consequently, the development of chicks within broods shows substantial variation (Inoue 1985). Several of the above papers have reported that later hatched chicks grow more slowly and the brood reduction stems primarily from the death of these youngest chicks in asynchronously hatching species. Nevertheless, few behavioral studies on feeding behavior and sibling interactions in Asian Openbill storks exist.

4.1.2 Pair and Extra-Pair Copulatory behavior: In most bird species considered socially monogamous, extra-pair copulations (EPCs) have been observed, suggesting that among males, EPCs are part of a mixed reproductive strategy (Trivers 1972; Birkhead & Moller 1992). EPCs have been reported for many colonial birds (Gladstone 1979; Fujioka & Yamagishi 1981; Werschkul 1982; McKinney et al. 1984; Ramo & Busto 1985; Frederick 1987; Aguilera & Alvarez 1989; McKilligan 1990; Tortosa & Redondo 1992). High copulation rates and mate guarding among these birds have been interpreted as paternity defense (sperm competition hypothesis, Birkhead et al. 1987). This study tried to answer the following question: Is the frequency of

PCs and the intensity on mate guarding higher when cuckoldry is more likely to occur?

4.1.3 Spatial location and reproductive success: Reduced probability of predation among large breeding colonies is one major hypothesis explaining colonial nesting (Wittenberger and Hunt 1985; Brown and Brown 1987; Wiklund and Andersson 1994). Lower rates of nest predation potentially occur because of early detection of predators, effective deterrence of predators by group mobbing and defense, or predator swamping (Wittenberger and Hunt 1885). Furthermore, predator avoidance may be achieved through the “selfish herd” effect, and individual’s survival is determined by the number of its immediate neighbours. Because peripheral nests have neighbours only on one side, the selfish herd hypothesis predicts that individual’s breeding at the edge of the colony should suffer higher losses due to predation than individuals breeding near the center (Tenaza 1971; Hoogland and Sherman 1976). The main assumption of this hypothesis is that predators are equally likely to approach from any direction. There also is a further assumption that individuals compete for central positions. Hamilton’s (1971) hypothesis does not assume that individuals show antipredator behaviour towards predators (Hoogland and Sherman 1976). The “Selfish herd” concept has been extended to predict the center as the optimal location for a nest within a colony (Tenaza 1971). Thus, predators should encounter peripheral nests first, and would be exposed to less severe mobbing on the periphery. Breeding success may differ between center and edge nests (Coulson 1968; Balda and Bateman 1972, Brown and Brown 1987), but is always not attributable to predation (Coulson 1968; Bunin and Boates 1994). Location differences may be confounded by factors such as the slope, colony accessibility, food supply, nesting density, and quality of birds choosing to nest in these areas (Siegel-Causey and Hunt 1981; Frederick and Collopy 1989; Bunin and Boates 1994).

4.1.4 Sub-objectives: The majority of published information on the ecological requirements of the colonial waterbirds of Bhitarkanika comprises anectodal notes. There is no information available on several aspects of breeding biology and productivity of the birds breeding in the Bhitarkanika heronry. This chapter quantitatively documents and describes the several aspects of breeding biology including arrival, departure patterns, clutch size, reproductive success, incubation behaviour, morphomentry of egg, chicks and fledglings, proportion of Nest materials in various nesting stages etc.

4.2 Methods

4.2.1 Heronry census to enumerate nests: The heronry censuses were conducted in the last week of August 2004, 2005 & 2006, just after the hatching process of most birds was over. A total count of nest trees was carried out in the heronry. All the trees in the heronry were marked numerically in increasing order by paint. Parameters like, tree species, tree height, Girth at Breast Height (GBH), species nesting on the tree, number of nests, and nest height were recorded. Nest height and tree height were visually estimated to the nearest *ft*. GBH was measured with a measuring tape in *cm*. The nest of the bird species was identified by looking at the species guarding the nests and during the absence of both the parents, the nest design and nest materials were used to identify the species nest.

4.2.2 Arrival and Departure patterns: Data were collected on the pattern of arrival of the birds in the heronry by carrying out regular surveys in the area every day during the beginning of the nesting season. Birds were observed with a spotting scope from a vantage point (a wooden *machhan*) close to the periphery of the heronry during the daily surveys to ascertain their pattern of arrival. Some selected trees in the sub colonies were marked before the start of nesting season with visible markers (with white cloth) so that they could be recognized from a distance. These markers were removed from the colony after the nesting season. Once the birds start nesting, the selected nesting trees in the colony were monitored from the vantage point to collect data on breeding biology. Departure patterns were also recorded towards the end of the season after fledglings were observed for the first arrived species.

4.2.3 Nest monitoring: For close examination of the nests, entries were made inside the colony during early morning hours to avoid overheating of eggs and embryos and to minimize predation. Nest trees were selected prior to nesting and were marked with red paint and also a white cloth was tied across the tree for easy identification on subsequent visits. Once nest building started, each nest was marked with a red oxide paint on a small aluminum tag with a chord attached tied below the branch that supported the nest, out of sight of the bird, with the tag bearing the alphanumeric code to identify individual nests. By using a graduated pole with a mirror, the height and contents of the nest were checked. Regular rainfall data along with daily temperature, humidity were collected at the base camp to correlate climatalogical data with the breeding biology of the birds. Mean laying date was obtained from subtracting mean hatching date from mean incubation period of different species (Voisin, 1991). Nest checks were done every alternate day and the status of each nest was noted. Nest checks were concurrently done by 2 observers in different parts of the colony. All observations were restricted to the cooler parts of the day (06.30 AM to 0800 AM) to avoid over-heating while handling the eggs. The entire colony was not disturbed more than 1 hour per monitoring. Birds left the nest while observers were within 2 to 5 m. However, birds returned immediately to their nests once the observer moved away. Nest progress was followed until the chicks fledged. Nest checks continued till the last chick had fledged from the colony. Nest monitoring was carried out thrice in a week until a pair abandoned its territory or reared chicks to fledging age. Nests were considered active on laying first egg and successful when atleast one young was raised to an age at which they were capable of escape by walking (14 days). (Fredrick and Callopy 1989). Since, rates of nest mortality were likely to vary with nesting stage; reproductive success was calculated separately for laying (0-6 days) and incubation period (7-21 days). An overall success rate was then calculated by combining these period specific estimates. Parameters such as species date of egg laying, clutch size, hatching success and hatchling survival were collected from each of these marked trees. Nest dimensions like External width, internal width (Bowl width) were also recorded. To study the asynchronous laying, eggs laid in the marked nests were numbered with permanent markers; the eggs were measured to determine whether egg size varies with order of laying.

We considered young successfully fledged when they were old enough to fly across open space to trees away from the nests. Nest were approached along one route and left by another. This would minimize predators to determine exact nest locations from watching observer's activity or following scent trails. For studying nest morphometry, nests circumference and width was measured using an inch tape. Hatching success was calculated by considering a nest as successful with hatching of a single egg. Productivity was calculated as number of chicks that survived till the fledglings dispersed from the nest.

Center and Edges are not easily defined in many colonies, especially those with irregular geometry. Teneza (1971) and Spurr (1975) defined the edge as a single row of nests bordering a colony. Edge clusters will be those, beyond which no other species would be nesting and Central clusters will be surrounded by other clusters. Reproductive success were determined and compared between central and peripheral clusters.

4.2.4 Description of Variables used in Analysis:

Spatial Location of the nests (SLN): Center and edge nests are not easily defined in many colonies, especially with irregular geometry. Tenaza (1971) and Spurr (1975) define the edge as a single row of nests bordering a colony. For the purpose of our study, we focused attention on nest clusters of nests. Edge clusters were those beyond which no other birds were nesting, while center ones were surrounded by other clusters.

Nest Initiation date (NID): Date in which first few nest materials were placed in the marked tree.

Clutch initiation date (CIND): Date that first egg was laid.

Clutch size: The clutch size for each nest used in the analysis was total number of eggs in each nest. Nests that failed before full clutch size was reached were excluded from the analysis.

Nearest-neighbor Distance: The shortest distance from the focal nest to a neighboring nest.

Predation: I considered a nest predated if evidence of predation (broken eggs, yolk in nest) was found at the nest scrape or in the nearby vicinity. In addition, eggs that disappeared before they should have hatched were considered predated.

Abandoned nests: Nests were considered abandoned when eggs were felt to be cold to the touch, or when they were present more than 5 days beyond the expected hatch date.

Egg morphometry: Length (L) and breadth (B) of each egg were measured to the nearest 0.1 mm using calipers. Measuring egg volume especially in the field has, however, been difficult because of the highly variable shape of bird eggs, and investigators have developed a series of mathematical expressions that enable them to use an egg's dimensions to ascertain its volume (literature summarized in Hoyt 1979; Smart 1991). Perhaps the most widely used equation is that of Hoyt (1979), in which the volume of an egg (V, in cm^3 can be obtained from its length (L, in cm) and breadth (B, in cm) using the formula $V = 0.51LB^2$. Total clutch volume was determined by summing volumes of each egg in a clutch.

Behavioral Observations: Used focal-animal sampling (Altmann 1974) for the behavioral observations. I randomly selected an individual bird and observed it for as long as the bird was visible, for a maximum of 4 hours per sample. I discarded all observations of less than 1 minute. I recorded incubation bout duration, incubation interval time and behavioral responses during incubation like aggression towards intruding birds, mating, steeling of nest materials, nest arrangements and changing duties for incubation and nest material collection respectively.

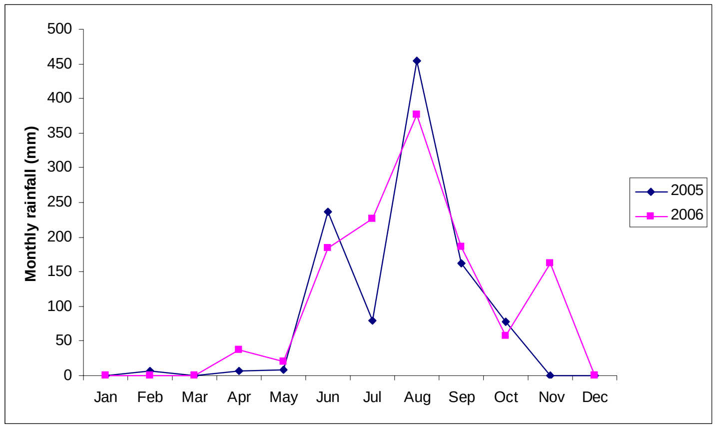
4.3 Results and Discussion

4.3.1 Breeding season Vs Monsoon pattern: Ali and Ripley (1968) points out that the breeding season of the colonial waterbirds are highly dependent on monsoon and water conditions which triggers the food abundance., hence the breeding season of colonial waterbirds is so regulated that it coincides with the time of availability of food supply. This study also shows a strong relation between the monsoon and the nesting activity of the colonial waterbirds (Fig. 4.1). All the breeding storks, herons and egrets in India, breed just after monsoon (Ali 1996). Most bird species breed around the time when food supplies are readily available (Thompson 1950).

4.3.1 Enumeration of nesting species and nesting trees: A total count of nest trees and number of nests carried over the past three years revealed the presence of 13,704 nests in 3839 trees (2004), 11,249 nests on 3,237 nest trees (2005), 11,819 nests on 4,221 trees (2006) (Fig.4.2). The nesting species In decreasing order of abundance are Asian Openbill, Large Egret, Little Cormorant, Intermediate Egret, Purple Heron, Night Heron, Grey Heron, Oriental Ibis, Oriental Darter, Cattle Egret and Little Egret. Asian Openbill accounts for nearly 66% of all the nests counted in the heronry and little egrets had the least number of nests of 0.6%.

Fig. 4.1. (a) Monthly rainfall in Bhitarkanika mangroves (b) Number of enumerated nests in each month by all the nesting species

(a)



(b)

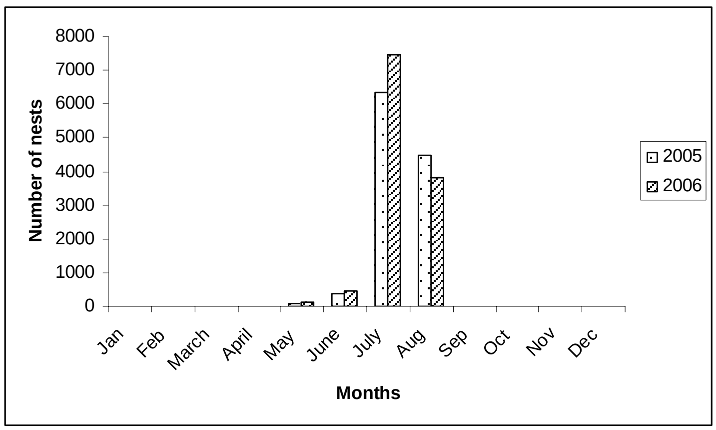
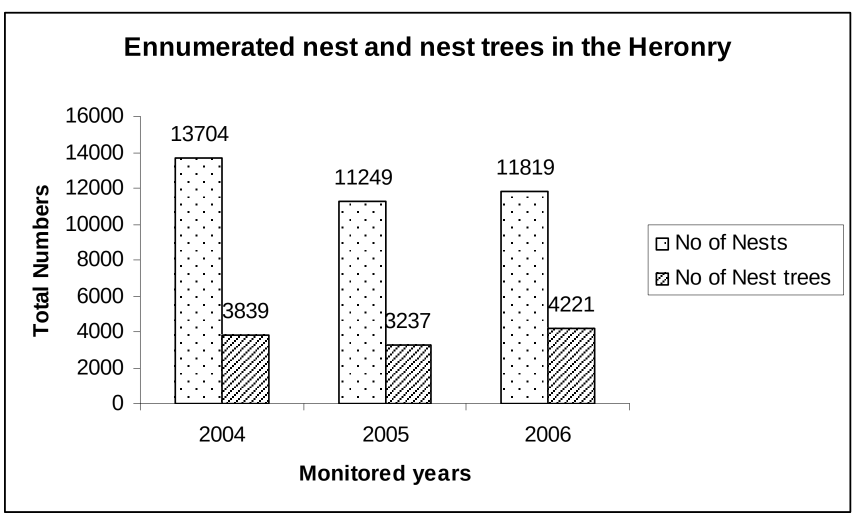


Fig. 4.2 Enumerated nest and nest trees in the Heronry



4.3.2 Arrival and Departure patterns: Darters are first to arrive in the heronry and the first pair of Darters were observed on 3-4th week of May in 2004 and 2006 but in 2005 arrived to the heronry during June 27th due to a delayed onset of monsoon, subsequently on arrival and settlement they started choosing partners. Large egrets, Grey heron, Purple heron, Intermediate egret were all seen courting and nest building from the first week of July. In 2005, though Asian Openbill storks arrived with most of these birds, they showed no evidence to settle down in the heronry. Openbill started settling only during mid July. Asian openbill stork tend to settle in the heronry only after the proper onset of monsoon since, monsoon is vital during their breeding phase. Monsoon aids in bringing the apple snail (*Pila globosa*) undergoing aestivation out of the soil after the rains in the paddy fields. Asian openbill stork predominantly (99%) feed only on Apple snails. Night heron and White Ibis are the late arrivers to the heronry. Departure pattern followed the similar pattern of arrival i.e. early arrivers departed early. Darters departed from heronry during early October followed by egrets and herons. Asian openbill and white Ibis were last to leave the heronry during mid January. However some openbill fledglings were observed till January last week in the heronry. Delay in the monsoon during this season is presumed to be the major reason for delay in the nesting process of Asian openbill storks.

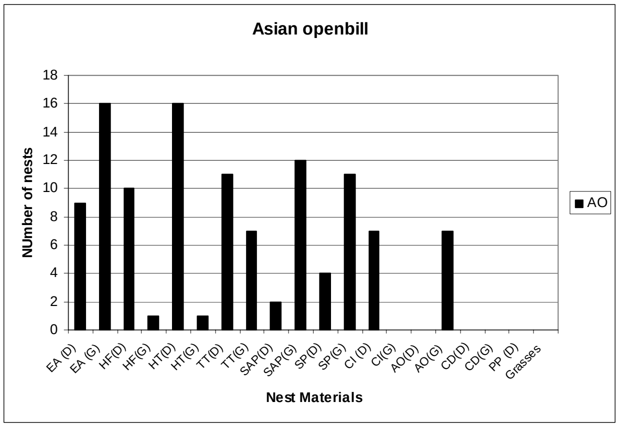
4.3.3 Nest biology: During the breeding season, a bird's nest provides an environment for its eggs and chicks to develop safely. Some birds don't build a nest, but instead lay their eggs directly on the ground, in a hole, or even on a bare branch. In other species, nests are elaborate works of avian architecture. Birds make a variety of nests like ground, cavity, platform nests and modified cupped nests etc. Nest size, shape, and building materials vary greatly among birds. Nest placement and design, along with the behavior of the parents and young; combine to provide protection from temperature extremes and from predators. All the nesting species in the Bhitarkanika heronry build “platform nests” which consists irregularly placed and loose assemblages of plant materials. The platform nests are very simple in structure. Essentially they are flat areas with a very slight depression to hold the eggs. Mostly of the nest materials are chosen from the immediate surroundings which result in inconspicuous or camouflaged nest. Nest profile in the heronry varied between species in relation to the body mass (Table.4.1). Grey heron built the largest nest size in contrast to little cormorant building the smallest nest with few sticks in them. The nest size correlated to the body mass index of the nesting species i.e., larger the body mass of the species, larger were the nest morphometry.

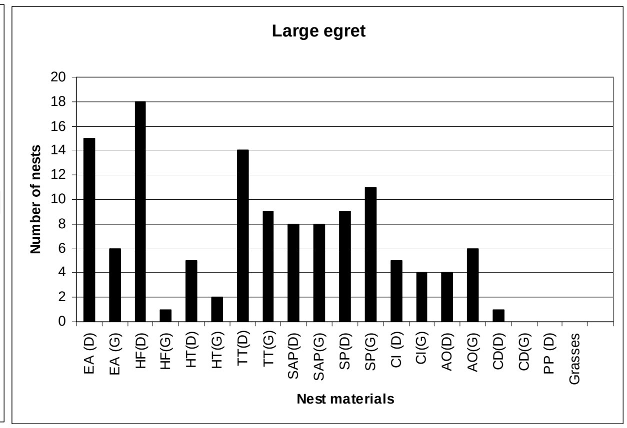
Table.4.1 Nest measurements of breeding species

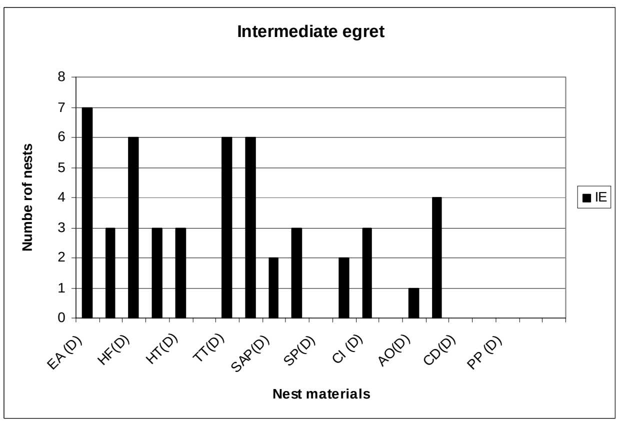
Species	**n**	**Nest Measurements (cm)**	
		Circumference	**Width**
Asian Openbill	20	166.1± 16.3	52.1 ± 6.3
Large egret	30	172.83 ± 13.0	50.3 ± 4.9
Intermediate egret	10	144 ±7.21	45.66 ± 8.50
Little egret	5	168.5 ± 13.86	43.5 ± 4.10
Grey heron	20	217.17 ± 19.05	66.17 ± 11.46
Purple heron	10	169.00 ± 16.66	55.00 ± 8.62
Night heron	4	132 ± 7.25	32 ± 4.86
Darter	20	162.25 ± 19.15	43.25 ± 7.5
Little cormorant	11	128 ± 11.96	34 ± 3.0
White Ibis	10	155.66 ± 44.33	9.50 ± 6.11

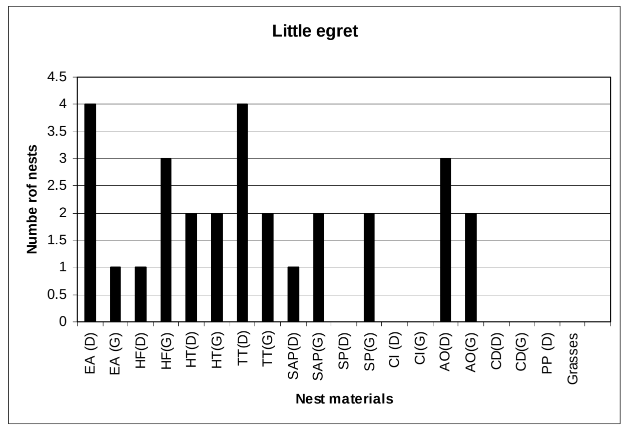
4.3.4 Nest materials used by nesting species: Nest materials that were collected and used for nest building were as follows: *Excoecaria agallocha* (Dry and Green twigs), *Heritiera fomes* (Dry and Green twigs), *Hibiscus tiliaceus* (Dry and Green twigs),*Tamarix troupii* (Dry and Green twigs), *Cynometra iripa (*Dry and Green twigs), *Salvodora Perscica* (Dry and Green twigs), *Salacia prinoides* (Dry and Green twigs),, *Avivienia officianalis* (Dry and Green twigs), *Ceriops decandra* (Dry and Green twigs) and one instance of *Phoenix paludosa* green leaves in Darters nest material (Fig.4.3). There is a significant increase in the proportion of nest materials and size with increase in the breeding stage i.e. Laying, hatching and fledgling stage (Table.4.2). Nest materials were added by both parents till the chicks fledged in all the species to provide enough space for the growing chicks to reside in the nest.

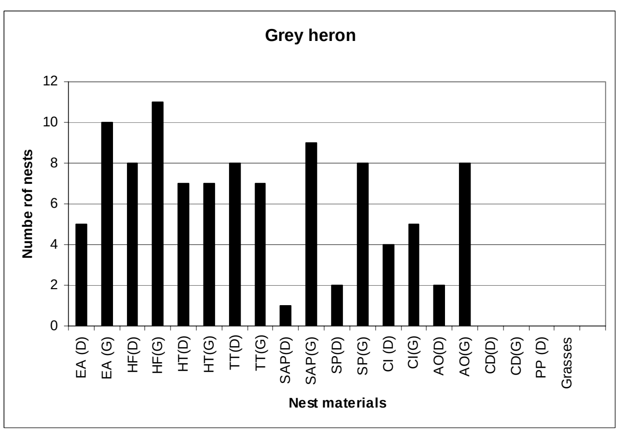
Fig. 4.3 Various nest materials used by nesting birds:

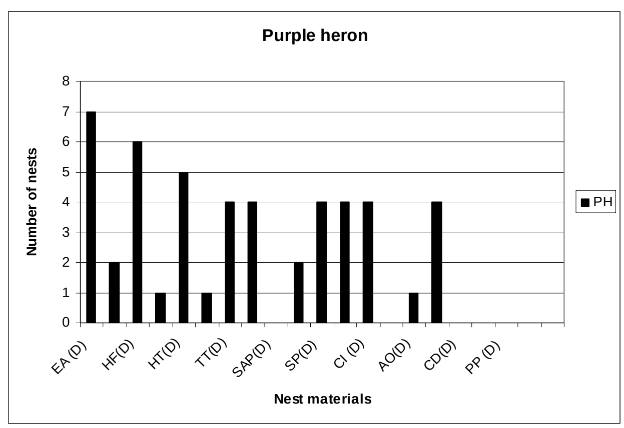


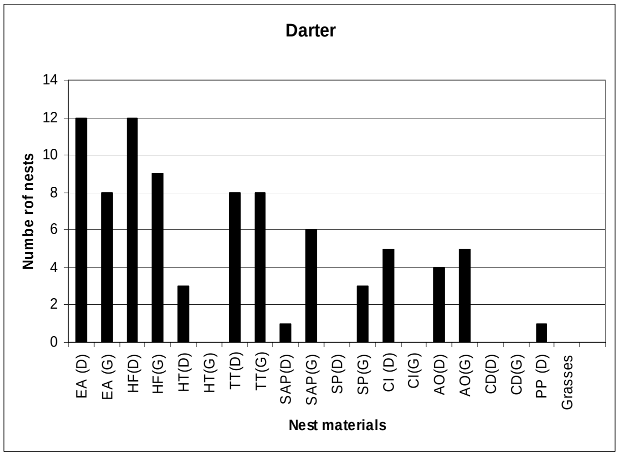


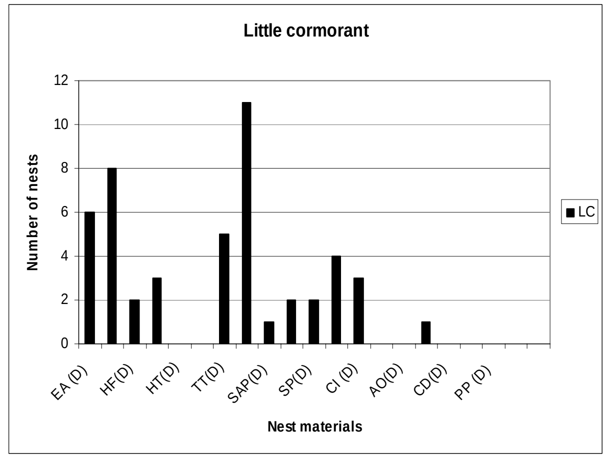


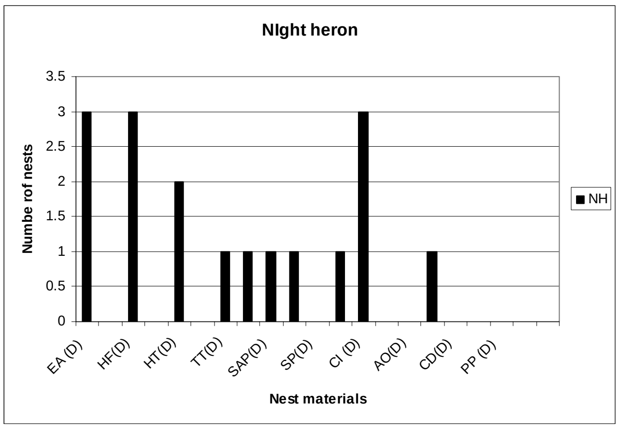







Darter
Numbe rof nests
14
12
10
8
6
4
2
0
EA (D)
EA (G)
HF(D)
HF(G)
HT(D)
HT(G)
TT(D)
TT(G)
SAP(D)
SAP(G)
SP(D)
SP(G)
CI (D)
CI(G)
AO(D)
AO(G)
CD(D)
CD(G)
PP (D)
Grasses
Nest materials


Little cormorant
Number of nests
12
10
8
6
4
2
0
LC
EA (D)
HF(D)
HT(D)
TT(D)
SAP(D)
SP(D)
CI (D)
AO(D)
CD(D)
PP (D)
Nest materials


NIght heron
Numbe rof nests
3.5
3
2.5
2
1.5
1
0.5
0
NH
EA (D)
HF(D)
HT(D)
TT(D)
SAP(D)
SP(D)
CI (D)
AO(D)
CD(D)
PP (D)
Nest materials

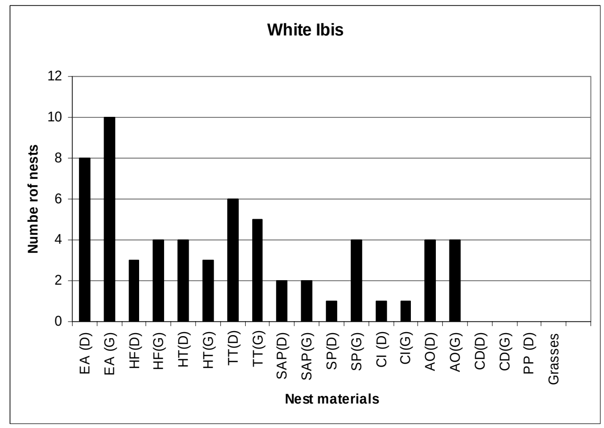

White Ibis
Numbe rof nests
12
10
8
6
4
2
0
EA (D)
EA (G)
HF(D)
HF(G)
HT(D)
HT(G)
TT(D)
TT(G)
SAP(D)
SAP(G)
SP(D)
SP(G)
CI (D)
CI(G)
AO(D)
AO(G)
CD(D)
CD(G)
PP (D)
Grasses
Nest materials

Table.4.2 Proportion of Nest materials in various nesting stages (Laying, hatching and fledgling):

Species	Friedman rank chi-square	N	df	p-value	Result
Asian Openbill	10	20	2	0.007	Sig
Large egret	10	20	2	0.007	Sig
Grey heron	10	20	2	0.007	Sig
Oriental darter	10	20	2	0.007	Sig
Purple heron	10	20	2	0.007	Sig
Little cormorant	10	20	2	0.007	Sig
Intermediate egret	8	20	2	0.018	Sig
Night heron	2	20	2	0.368	Non-sig
White Ibis	6	20	2	0.05	Sig
Little egret	10	20	2	0.007	Sig

4.3.4 Egg morphometry of nesting species: Egg morphometry studies revealed White Ibis to produce larger eggs both in terms of length and mass while little cormorant produced smaller eggs both in terms of length and total mass (Table.4.3).

Table. 4.3 Egg morphometry of breeding species

Species	N	Mean egg length (mm)	Mean egg width (mm)	Mean egg mass (cm^3)
Asian Openbill	84	42.06± 8.48	26.96± 5.38	16.84 ± 3.92
Large egret	74	37.22± 8.17	24.91± 5.82	13.01 ± 4.44
Intermediate egret	30	33.67± 2.31	22.77± 1.83	9.00 ± 1.90
Little egret	19	30.58± 2.57	20.58± 1.17	6.59 ± 0.60
Grey heron	64	43.30± 6.00	29.59± 4.92	20.18 ± 5.37
Purple heron	51	40.33± 6.37	25.96± 4.52	14.66 ± 4.49
Night heron	13	33.46± 2.26	21.08± 1.98	7.70 ± 1.95
White ibis	60	51.15± 2.66	30.03± 1.82	23.68 ± 3.37
Little cormorant	49	32.18± 5.25	15.92± 2.98	4.39 ± 1.11
Darter	98	37.96± 6.17	20.07± 3.23	8.19 ± 1.82

4.3.5 Variability in NID and CID across species*:* The variability in the Nest Initiation Date to Clutch Initiation Date revealed 8-10 days for herons and egrets, while cormorants and darters took 15-18 days to initiate the clutch. Asian openbill's showed a delayed clutch initiation of 30 days after nest initiation (Table.4.4). This delay in initiation is presumably due to the delay in Monsoon.

Table.4.4 Variability in NID and CID across species

Species	N	Mean number of difference in days
Asian Openbill	20	30.53 ± 8.50
Large egret	30	9.19 ± 3.50
Intermediate egret	10	9.67 ± 3.97
Little egret	5	8.40 ± 3.21
Grey heron	20	10.17 ± 11.62
Purple heron	12	8.08 ± 1.83
Night heron	5	5.20 ± 1.79
White ibis	10	5.50 ± 0.71
Little cormorant	11	16.82 ± 9.54
Darter	20	18.89 ± 9.41

4.3.6 Clutch size: Clutch size varied between 2.5 eggs to 6 eggs per clutch across all species. White Ibis had the mean largest clutch size followed by darter and Night heron and large egret showed mean lesser clutch size with less than 3 eggs per clutch (Table.4.5).

Table. 4.5 Mean clutch size of breeding species

Species	Clutch size
Asian Openbill	4.36 ± 2.90
Large egret	2.84 ± 1.18
Intermediate egret	3.33 ± 1.80
Little egret	3.8 ± 1.09
Grey heron	3.70 ± 1.53
Purple heron	4.25 ± 1.86
Night heron	2.6 ± 0.54
White Ibis	6 ± 2.16
Little cormorant	4.45± 1.36
Darter	5.17 ± 1.42

The determinants of clutch size in birds have long been a focus of speculation and experimentation in evolutionary ecology (Stearns 1976, 1992). Of all the theories put forward to explain the evolution of clutch size in birds, the food limitation hypothesis of Lack (1947, 1954 and 1968) has gained the most acceptances. Simply put, Lack's hypothesis holds that 1. Observed clutch sizes represent an optimum and 2. The optimal clutch size reflects a food limited tradeoff between offspring number and offspring survival. Several workers have extended Lack's ideas to include aspects of environmental stability and competition (Ashmole 1963; Cody 1966; Ricklefs 1980; Koenig 1984) in an effort to explain many of the geographical trends in clutch size in birds (Crowell and Rothstein 1981). Hogsted (1980) proposed that clutch size variations within populations are adaptive and that each female lays a clutch that corresponds to the number of young that can be raised in her particular situation (Klomp 1970). Unless the average female is in the most favourable habitat, the modal clutch size will be lower than the most productive clutch size. Numerous environmental factors other than food supply during the nestling period, for example, predation (Slagsvold 1982) or food supply for fledglings may influence the evolution of clutch size and favour a modal clutch size that is smaller than the most productive clutch size.

The probability of predation probably is positively correlated with clutch size for any of many potential reasons (Slagsvold 1982). First, it will be positively correlated with duration of the nesting attempt that is equal to the interval between laying of successive eggs and additionally may extend the nesting period if growth and development rates of the young and negatively correlated with brood size (Bryant 1975; McGillivary 1983; Murphy 1983). Second is the risk of detection of the nest may increase with clutch size because of a larger clutch may require a larger nest (Snow 1962) or number of trips to and from the nests by parents may increase (Skutch 1949). Third, risk of detection will increase with brood size in those species in which under nourished young beg more intensely for food, if food stress is brood size dependent (Perrins 1979). Finally risk of predation on the parents may be positively correlated with the time and energy they invest in the attempt; both will be positively correlated with clutch and brood size.

4.3.7 Incubation duration of breeding species: Incubation started with onset of the first egg laying. White Ibis and Little egret showed the least mean incubation duration (18 and 19 days respectively) while darter and Asian Openbill showed larger mean incubation duration (28 and 26 days respectively) (Table 4.6).

Table.4.6 Incubation duration of breeding species

Species	n	Mean number of days
Asian Openbill	38	26 ± 2.84
Large egret	23	25.17 ± 1.40
Intermediate egret	13	25.70 ± 4.90
Little egret	14	18 ± 3.06
Grey heron	16	23.63 ± 2.31
Purple heron	30	24.73 ± 3.27
Night heron	12	23.25 ± 0.96
White ibis	23	19.56 ± 1.13
Little cormorant	15	22.10 ± 2.23
Darter	49	28.55 ± 8.86

In colonial waterbirds, both the sexes incubate the eggs (Lowe 1954; Blaker 1969; Milstein et al. 1970; Tomlinson 1976). This study also documented the incubation by both the parents for all the studied species.

4.3.8 Productivity: Productivity in terms of hatching and fledgling success was very low (< 50%) for most species and only purple heron and darters showed higher reproductive success with > 50% eggs surviving till fledgling stage (Table.4.7).

Table.4.7 Variability in hatching success across species

Species	n	Hatching Success %
Asian Openbill	20	45.24 ± 38.64
Large egret	30	33.07 ± 43.91
Intermediate egret	10	41.67 ± 43.30
Little egret	5	38.00 ± 37.52
Grey heron	20	22.22 ± 40.12
Purple heron	12	57.74 ± 36.62
Night heron	5	15.00 ± 33.54
White ibis	10	15.74 ± 21.43
Little cormorant	11	29.55 ± 43.04
Darter	20	50.22 ± 37.91

4.3.9 Reproductive success in relation to spatial location of nests (Core Vs edge): Since breeding success was known to differ between center and edge nests (Coulson 1968; Balda and Bateman 1972; Brown and Brown 1987) the reproductive success was compared between edge nests and core nests which revealed no difference in success rate, thus indicating reproductive success was random at both space and time immaterial of their spatial location (Table 4.8 & 4.9).

Table.4.8 Comparative Asian Openbill hatching success in central and edge nests

Nesting Variable	Mann-Whitney U	n	p-value
Clutch size	32.5	18	0.550
Clutch mass	24.0	18	0.189
Hatching success %	34.0	18	0.010
Fledgling success %	34.0	18	0.010

Table.4.9 Comparative Large egret hatching success in central and edge nests

Nesting Variable	Mann-Whitney U	n	p-value
Clutch size	56	25	0.231
Clutch mass	45	23	0.257
Hatching success %	55	25	0.013
Fledgling success %	55	25	0.013

It is widely assumed that edge or fringe nester should have a lower breeding success compared to center nesters (Wittenberger and Hunt 1985). Several authors have reported that edge or fringe nesters show higher levels of failure than more central nesters and that the center advantage increases as colony size increases (Kruuk 1968; Brown and Brown 1987; Spear 1993). Furthermore several studies have shown preferences by males for establishing territories within the center often colonies (Kittiwake, *Rissa* *tridactyla*, Coulson 1968; Least Terns, Burger 1988). The study clearly supports the hypothesis that edge nests suffer higher level of predation and demonstrates that the highest level of predation occur in the periphery. The "selfish herd" hypothesis predicts aggregative behaviour because edge individuals are at high risk. Wittenburger and Hunt (1985) suggest that as a general rule, the proportion of nests lost to predators will decrease with increasing colony size once the colony is large enough to "swamp" all the predators.

4.3.10 Chick hierarchical order Vs hatching success rate: Success rate was also independent of their hierarchical order except for Purple heron and Darter which showed significant relationship between the chick hierarchical order and hatching success rate (i.e. older the chick higher the survival possibility) (Table.4.10).

Table .4.10 Chick hierarchical order Vs hatching success rate

Species	n	Pearson's chi-square	p-value	Contingency coefficient
Asian Openbill	30	**7.249**	**0.005**	**0.051**
Large egret	38	0.991	0.319	0.159
Grey heron	34	0.000	1.000	0.000
Oriental darter	**34**	**3.114**	**0.078**	**0.029**
Purple heron	**22**	**8.250**	**0.004**	**0.052**
Intermediate egret	22	0.259	0.611	0.180
Night heron	16	0.000	1.000	0.000
White Ibis	16	0.000	1.000	0.000
Little egret	10	3.600	0.058	0.514
Little cormorant	22	0.259	0.611	0.108

*Correlation is significant at the .05 level (2-tailed).

Analysis done to check the relationship between Clutch size and Hatching success revealed nothing significant for most birds except for Darter and purple heron which showed negative significance (More the clutch size lesser the success rate) (Table.4.11).

Table. 4.11 Relationship between clutch size and hatching success

Species	n	Spearman's rho	p-value
Asian Openbill	20	-0.285	0.222
Large egret	25	0.192	1.000
Grey heron	18	0.392	0.108
Oriental darter	18	-0.378	0.122
Purple heron	12	-0.451	0.135
Intermediate egret	5	-0.229	0.710
Night heron	9	-0.027	0.945
White Ibis	9	0.046	0.906

*Correlation is significant at the .05 level (2-tailed).

4.3.11 Hatching Asynchrony and related growth morphometry: Growth rate of chicks were highly significant with age with older chicks showing better growth rate than the younger chicks across species. Hatching order also showed significant relationship with Culmen, tarsus and middle toe growth rate across species (Table 4.12 & 4.13). The difference in growth between siblings could be due to fact of Hatching asynchrony has generally been "Hatching Asynchrony", which is interpreted as an adaptive brood reduction mechanism (Lack 1954), resulting in the elimination of the youngest chicks during periods of food shortage without severe competition among brood members. Hatching synchrony though is more prevalent in hole nesters and enclosed nesters, it is also been observed to occur in the cup and platform nesters (Clark and Wilson 1981). Slagsvold et al. (1984) postulated that birds laying relatively small last eggs demonstrate the brood reduction strategy and those laying large last eggs fit the "nest failure" model. However, the relationship between relative size of the last egg and the comparative influence of food and predation has not been nearly so straight forward. Asynchronous hatching alone places even relatively large last eggs at a disadvantage when the parents cannot adequately provision the entire brood (Howe 1976, 1978; Murphy 1978; Zach 1978; Horsfall 1984; Mead and Morton 1985). The hatching interval is regulated proximately by the length of the egg laying period, when incubation starts (Gibb 1950; Haftorn 198; Mead and Morton 1985), incubation efficiency for each egg (Neub 1979), egg quality (Bryant 1978). The evolutionary significance of such hatching patterns is poorly understood (Clark and Wilson 1981). Synchronous hatching of eggs is usually considered to be favourable (Lack 1954) partly because of brood of nestlings that are a similar age may be more easily cared for once they have left the nests (Lack 1968). Lack (1947, 1954, 1966) also proposed that asynchronous hatching may be advantageous during periods of food shortage because of young nestlings can be rapidly eliminated without too much loss of already invested energy (the brood reduction hypothesis, Ricklefs 1965). This hypothesis won early acceptance among bird ecologists and some support has been found (Hahn 1981; Slagsvold 1982; Fujioka 1985). Critical tests and experiments are nevertheless still needed. In a review on asynchronous hatching in birds, (Clark and Wilson 1981) claimed that data for many atrical birds do not support brood reduction hypothesis. They found that within brood loss was often associated with little or no asynchrony and also that loss with asynchrony could be insufficient.

Table . 4.12 Hatching order and growth rate in four morphometric variables (WT, TL, MT,CL):

Species	Friedman rank chi-square	N	df	p-value	Result
Asian Openbill	21.34	16	2	0.000	Sig
Large egret	16	16	1	0.000	Sig
Grey heron	20.512	12	2	0.000	Sig
Oriental darter	26.39	16	3	0.000	Sig
Purple heron	6.203	16	2	0.045	Sig
Intermediate egret	22.557	16	2	0.000	Sig
Night heron	11.267	16	1	0.001	Sig
White Ibis	29.746	16	2	0.000	Sig

Table. 4.13 Hatching order and morphometric variables (WT, TL, MT, and CL) across species:

Species	Friedman rank chi-square	N	df	p-value	Result
Culmen length Vs hatching order	18.828	23	2	0.000	Sig
Tarsus length Vs hatching order	15.432	23	2	0.000	Sig
Middle toe Vs hatching order	16.381	23	2	0.000	Sig
Body weight Vs hatching order	24.299	23	2	0.000	Sig

4.4 Summary of findings

There was significant change in the nest profile during various stages. Asian Open bill, Grey heron, White ibis, Large egret, Little cormorant, Intermediate egret, Little egret showed < 50% success rate and Purple heron, Oriental darter showed > 50% success rate. Asian Openbill showed delayed Clutch Initiation Date compared to other species from Nest Initiation Date, probably due to delay in Monsoon in both years. White ibis and Little egret had the least incubation duration, Oriental darter and Asian Openbill had larger incubation duration. Night heron and Large egret had the least clutch and White ibis and Oriental darter had larger clutches. Reproductive success was random at both space and time immaterial of their spatial location at the heronry, disproving the well proven hypothesis that breeding success may differ between centre and edge nests in colonial breeders. Success rate is independent of their hierarchical order except Purple heron and Oriental darter which shows significant relation between hierarchical order & hatching success rate. Oriental darter and Purple heron showed negative-significance (More the clutch size, lesser the success rate) & for other species, no significance was obtained between clutch size and hatching success). Marked significance in growth rate difference was observed between Older and younger chicks, with older chicks showing better growth rate than the younger chicks.

4.4.1 Asian Openbill storks: Ali & Ripley (1987) state that the breeding season of storks is highly dependent on the monsoon and related water conditions, which trigger the abundance of food. This study also shows a strong relation between the monsoon and the nesting activity of storks. The Openbill stork had the mean clutch size of 4.45± 1.36 and 4.36 ± 2.90 in 2005 and 2006 respectively. (Ali & Ripley 1968) reports that Asian Openbill lay 2-4 eggs and rarely 5 eggs. In Bhitarkanika most of the clutch examined contained more than 4 eggs. Egg morphometry studies revealed Openbill storks to produce smaller eggs both in terms of length and mass in comparison to the other storks (Gopi and Pandav 2007). Chicks hatched after an incubation period of approximately 25 to 26 days. Lack (1968), states that in Ciconiiformes, successive eggs in a clutch are laid two or more days apart, that incubation starts with the first egg, and that the young hatch one or more days apart, and this study confirms the fact. The results of Asian Openbill egg morphometry revealed that the average size of the eggs were 42.06± 8.48 and 26.96± 5.38 (N=84) but however, this result completely differed from that of (Ali & Ripley 1968) who documented the egg size of Asian Openbill to be 62.9 X 47.4 (N=100). According to Lack (1968), the incubation period in ciconiidae varies between 30 – 33 days. Incubation period in Asian Openbill had the minimal incubation period of 26 ± 2.84 days compared to any other stork species. In Bhitarkanika the focal species seemed to have shortened incubation duration compared to the normal incubation duration provided by Lack, 1968. Incubation periods for other storks are: Greater Adjutant-Stork 30 and 35 days reported by Saikia & Bhattacharjee (1996b) and Singha *et al*. (2003) respectively; American Wood-Stork *M. americana* 32 days (Heinzman & Heinzman 1965); White Stork *C. ciconia* 32 days (Schuz 1972); Maguari Stork 29–32 days (Thomas 1984, 1986); Painted Stork 32 days (Desai et al. 1978); Whitenecked Stork *C. episcopus* 30–31 days (Scott 1975); Abdim's Stork *C. abdimii* 28–30 days and, 29–31 days for Marabou Stork *L. crumeniferus* (Brown et al. 1982; Kahl 1972; Pomeroy 1978a). Though prolonged incubation period has been reported in many stork species including painted stork (Desai et al, 1977), Marabou stork (Pomeroy, 1978a), and reasons could not be ascertained for the shorter incubation duration of storks in Bhitarkanika. Copulation duration of the Openbill stork was 7.45 ±

1.25 seconds (n=75). The findings of asynchronous hatching investigation support Lacks (1954, 1966) hypothesis that asynchronous hatching may be an adaptation by which brood size can be adjusted to correspond with unpredictable food availability; when food is scarce, only the weaker chick(s) in a brood die of starvation (total brood loss is avoided), but when food is plentiful, all chicks are raised. Our data support the hypothesis of a Mixed Reproductive Strategy (Trivers 1972; Birkhead & Moller 1992) in the Asian openbill stork, since the occurrence of EPCs at Bhitarkanika heronry seems to be a common phenomenon, most of the individuals involved in EPCs were paired, and most of the EPCs occurred during the presumed fertile period of the female. Mate guarding and frequent pair copulation is the main behavioural adaptations to paternity guards. They are an efficient way for males to increase certainty of paternity, although their effectiveness should be assessed by DNA fingerprinting or some similar technique (Birkhead & Moller 1992).

4.4.2 Oriental Ibis: Oriental ibis builds platform nests and forms sub colonies inside the heronry. The circumference and width of the nests were 155.66 ± 44.33 and 9.50 ± 6.11 (in cm & N= 10). The nest materials were significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird species build the nests very quickly on arrival to the heronry and they just took 5.50 ± 0.71 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 2 - 4 eggs but however, in Bhitarkanika most of the clutch examined contained more than 4 eggs and in fact the clutch size was the highest 6 ± 2.16 when compared with other species in the Bhitarkanika heronry. The results of Oriental white ibis egg morphometry revealed that the average size of the eggs were 51.15± 2.66 and 30.03± 1.82 (N=60) but however, this result completely differed from that of (Ali & Ripley 1968) who documented the egg size of Oriental white ibis to be 63.5 X 43.1 (N=150). The incubation period of the bird species in the heronry was 19.56 ± 1.13 days. There is a slight variation in the incubation period cited by Ali & Ripley (1968) who reported 23-25 days. Hatching success was very poor 15.74 ± 21.43 (*in %,* n= 10).

4.4.3 Oriental Darter: Darters builds platform nests and the circumference and width of the nests were 162.25 ± 19.15 and 43.25 ± 7.5 (in cm & N= 20). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 18.89 ± 9.41 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 - 5 eggs, in Bhitarkanika the clutch size was highest 5.17 ± 1.42 confirming with Ali& Ripley (1968). The results of darter egg morphometry revealed that the average size of the eggs were 37.96± 6.17 and 20.07± 3.23 (N=98) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere (Ali & Ripley 1968) who documented the egg size of oriental darter to be 44.8 X 29.0 (N=100). The incubation period of the bird species in the heronry was 28.55 ± 8.86 days (n=49). There is a slight variation in the incubation period cited by Ali & Ripley (1968) who reported 23-25 days. Hatching success was 50.22 ± 37.91 (n=20).

4.4.4 Grey Heron: Grey herons builds platform nests and the circumference and width of the nests were 217.17 ± 19.05 and 66.17 ± 11.46 (in cm & N= 20). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 18.89 ± 9.41 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 – 4 eggs and occasionally 5 eggs, in Bhitarkanika the clutch size was 3.70 ± 1.53 confirming with Ali& Ripley (1968). The results of Grey heron egg morphometry revealed that the average size of the eggs were 43.30± 6.00 and 29.59± 4.92 (N=64) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (58.6X 43.5 n= 100) who documented the egg size of oriental darter to be 44.8 X 29.0 (N=100). The incubation period of the bird species in the heronry was 23.63 ± 2.31 days (n=16). The results confirms with the incubation period cited by Ali & Ripley (1968) who reported 25-26 days. Hatching success was 50.22 ± 37.91 (n=20).

4.4.5 Purple heron: Purple herons builds platform nests and for forms sub colonies inside the heronry. The circumference and width of the nests were 169.00 ± 16.66 and 55.00 ± 8.62 (in cm & N= 10). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 18.89 ± 9.41 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 - 5 and rarely 6 eggs, in Bhitarkanika the clutch size was 4.25 ± 1.86 confirming with Ali& Ripley (1968). The results of purple heron egg morphometry revealed that the average size of the eggs were 40.33± 6.37 and 25.96± 4.52 (N=51) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (54.6X 39.7 n= 100). The results confirms with the incubation period of the bird species in the heronry was 24.73 ± 3.27 days (n=30). There is a slight variation in the incubation period cited by Ali & Ripley (1968) who reported 24-26 days. Hatching success was 50.22 ± 37.91 (n=20).

4.4.6 Night Heron: Night herons builds small platform nests and the circumference and width of the nests were 132 ± 7.25 and 32 ± 4.86 (in cm & N= 4). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 5.20 ± 1.79 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 or 4 or rarely 5 eggs, in Bhitarkanika the clutch size was 2.6 ± 0.54 confirming with Ali& Ripley (1968), except that in Bhitarkanika heronry never clutch was seen with more than 3 eggs. The results of egg morphometry revealed that the average size of the eggs were 33.46± 2.26 and 21.08± 1.98 (n=13) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (58.6X 43.5 n= 100) who documented the egg size of night heron to be 49.0 X 35.1 (n=50). The incubation period of the bird species in the heronry was 23.63 ± 2.31 days (n=16). Ali & Ripley (1968) could not ascertain incubation period for this species but suggest that many be 21 days and the results obtained in Bhitarkanika matches with their suggestion. Hatching success was 15.00 ± 33.54 (n=5), which was the least when compared among the other species.

4.4.7 Little cormorant: Little cormorants builds platform nests and the circumference and width of the nests were 128 ± 11.96 and 34 ± 3.0 (in cm & n= 11). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 16.82 ± 9.54 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 - 5, in Bhitarkanika the clutch size was 4.45± 1.36 confirming with Ali & Ripley (1968). The results of egg morphometry revealed that the average size of the eggs were 32.18 ± 5.25 and 15.92 ± 2.98 (n=49) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (44.8X 29.0 n= 100). The incubation period of the bird species in the heronry was 24.73 ± 3.27 days (n=30). Ali & Ripley (1968) could not ascertain incubation period for this species. Hatching success was 29.55 ± 43.04 (n=11).

4.4.8 Large egret: Large egrets builds small platform nests and the circumference and width of the nests were 172.83 ± 13.0 and 50.3 ± 4.9 (in cm & n= 30). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 9.19 ± 3.50 (n=30) days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 or 4, in Bhitarkanika the clutch size was 2.84 ± 1.18 slightly lower than Ali& Ripley (1968), except that in Bhitarkanika heronry never clutch was seen with more than 3 eggs. The results of egg morphometry revealed that the average size of the eggs were 37.22± 8.17 and 24.91± 5.82 (n=74) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (54.0X 38.6 n= 60). The incubation period of the bird species in the heronry was 25.17 ± 1.40 days (n=23). The results confirm with Ali & Ripley (1968) for incubation period of this species. Hatching success was 33.07 ± 43.91 (n=30), which was the least when compared among the other species.

4.4.9 Intermediate egret: Intermediate egret builds platform nests and the circumference and width of the nests were 144 ±7.21 and 45.66 ± 8.50 (in cm & n= 10). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 9.67 ± 3.97 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3, 4 or sometimes 5, in Bhitarkanika the clutch size was 3.33 ± 1.80 confirming with Ali& Ripley (1968). The results of egg morphometry revealed that the average size of the eggs were 33.67± 2.31and 22.77± 1.83 (n=30) this result shows that egg size in Bhitarkanika to be slightly smaller than recorded elsewhere by Ali & Ripley 1968 (47.6X 35.8 n= 60). The incubation period of the bird species in the heronry was 25.70 ± 4.90 days (n=13). Ali & Ripley (1968) could not determine incubation period for this species and suggested that it may 21 days. Hatching success was 41.67 ± 43.30 (n=10).

4.4.10 Little egret: Little egret builds platform nests and the circumference and width of the nests were 168.5 ± 13.86 and 43.5 ± 4.10 (in cm & n= 5). The nest materials significantly increased in all the stages (Laying, hatching and fledgling) during the nesting phase. The bird took 8.40 ± 3.21 days from nest initiation to clutch initiation. (Ali & Ripley 1968) reports that this bird lay around 3 - 5, in Bhitarkanika the clutch size was 3.8 ± 1.09 confirming with Ali& Ripley (1968). The results of little egret egg morphometry revealed that the average size of the eggs were 30.58± 2.57 and 20.58± 1.17 (n=19) this result shows that egg size in Bhitarkanika to be smaller than that recorded elsewhere by Ali & Ripley 1968 (44.4X 31.7 n= 60). The incubation period of the bird species in the heronry was 18 ± 3.06 days (n=14). Ali & Ripley (1968) have suggested a incubation f 21-25 days for this species and this study revealed a much lower incubation duration for this species. Hatching success was 38.00 ± 37.52 (n=5).

Plate no. 4 Asian openbill storks collecting nest materials. Nest building and renovation takes place throughout the nesting season with significant increase in the nest size from egg laying stage to fledgling stage (Photo © Gopi.G.V)

Plate no. 5 All the nesting species in the Bhitarkanika heronry build “platform nests”. Grey heron built the largest nest size in contrast to little cormorant building the smallest nest with few sticks in them. (Photo © Gopi.G.V)

Plate no. 6 Length (L) and breadth (B) of each egg were measured to the nearest 0.1 mm using calipers to document the egg morphometry of nesting species. (Photo © Gopi.G.V)

Plate no. 7 Asian openbill storks largely use *Excoecaria agallocha* twigs to build the nests. The nests are cushioned with fresh leaves and twigs before laying the eggs. (Photo © Gopi.G.V)

Plate no. 8 Incubation starts with onset of the first egg laying. The Mean incubation duration of Asian Openbill is 26 days in this heronry (Photo © Gopi.G.V)

Plate no. 9 Oriental darter fledglings in a nest aging 10 days to 20 days. The difference in age between the siblings of the same nest is due to the process of hatching asynchrony (Photo © Gopi.G.V)

Plate no. 10 Purple heron fledglings in a nest aging 2 days to 7 days. The difference in age between the siblings of the same nest is due to the process of hatching asynchrony (Photo © Gopi.G.V)

CHAPTER 5

RESOURCE PARTITIONING

5.1 Introduction

Differential resource selection is one of the principal factors, which permit species coexistence (Schoner 1974; Rosenwig 1981). In studies of niche partitioning, nest site location has received much less attention than food or habitat, perhaps because suitable nest sites are presumed to be readily available for most species. However, when a species has specific nesting requirements, suitable nesting locations may be difficult to obtain (Weins 1989; Burger & Gochfield 1990). This may bring about the overlap of nest sites and consequently, predation costs for breeders because of the attraction of the predators due to the increase in cumulative nest density (Martin 1996). Factors commonly identified to explain aggregations are the spatial availability of food and defense against predators (Emlen & Demong 1975; Birkhead & Furness 1985; Brown, Stutchaburuy & Walsh 1990). Other studies suggest that ectoparasitism and abiotic factors (Ex. Precipitation) affect habitat quality and become a dominant force influencing aggregation behaviour in birds (Hill and Levin 1989, Boulinger & Gavin 1989, Weins 1992, Bouliner & Lemel 1996). Differential resource selection is one of the principal factors, which permit species coexistence (Schoner 1974; Rosenwig 1981). The response of wild populations to their resources is not always predictable because of the outcome of the number of interacting factors, which may go since a single until multiple factors (Parish 1995). Food scarcity often leads to foraging in distant areas, which may result in formation of small colonies (Arengo & Baldasare 1995). Strong seasonal peaks in food resources may limit breeding to a single season o f the year and cause synchronized breeding of the population. In these cases large colonies are formed and intense competition occurs for food (Emlen and Demong 1975). Competition might be lessened by a strategy of fine scale temporal and spatial segregation in the use of habitats among species with similar feeding habits. (Murray 1971; Hill and Levin 1989). Anderson et al., 1979, suggested vertical stratification is believed to partition resources and thereby reduce competition among co-existing species.

Habitat selection and Nesting association: The environment of most animal species is heterogeneous at different spatial and temporal scales for various characteristics that can directly affect components of fitness. The process of habitat selection is thus likely to be under strong selective pressures (Cody 1985; Martin 1993). Animals can use variety of physical cues to assess environmental suitability (Buckley and Buckley 1980; Cody 1985; Danchin and Wagner 1997). More parsimoniously, they can use some integrative cue such as the presence and activities of conspecifics (Keister 1979; Shields et al., 1988; Stamps 1991; Boulinier and Danchin 1997). Gulls and Terns breed colonially due to similar habitat preferences, mutual advantages provided by better predator avoidance, and the possibility of exchange of information for food acquisition (Erwin 1979; Burger & Gochfield 1990b; Oro 1996; Rolland et al., 1998). On the other hand, colonial birds may compete for resources, and colonies may attract predators (Wittenberer & Hunt 1985; Krebs & Davies 1987; Siegel – Causey & Kharitonov 1990). Multiple factors drive colony site dynamics in waterbirds, depending on habitat quality (Kharitonov and Siegel – Causey 1988; Fasola & Alieri 1992; Boulinier and Lemel 1996; Erwin et al., 1998). Habitat composition around nesting sites has been so far the most studied of those across (Fasola & Alieri 1992; Baxter & Fairweather 1998). Since reproduction is a time of high energy demand (Drent & Dann 1980, availability of suitable foraging sites ill directly influence colony location, colony size and reproductive parameters.

Temporal segregation: Custer and Osborn (1978) found asynchronous nest building phases in North Carolina. Maxwell and Kale (1977) found Florida Caerulea, started to breed later than other colony species. Frederick and Callopy (1989) showed a strong difference for the nesting chronology of four species (*Casmerodius albus, Egretta tricolour, Egretta caerulea, Edocimus albus*) in Florida. Maxwell and Kale (1977) and Jenni (1969) found that nests of *Egretta thula* and *Bulbulcus ibis* showed an average nest height from 2.04

– 2.59 m. result of this work support the notion that species overlap temporally in breeding, also segregate vertically in nest placement within the colony.

Central – periphery distribution of nests: Breeding success may differ between centre and edge nests (Coulson 1968; Balda and Bateman 1972; Brown and Brown 1987), but it is not always attributable to predation (Coulson 1968; Bunin and Bates 1994). Nest defense against potential predators has long been suggested as an important force in the evolution of coloniality in birds (Lack 1968; Gotmark and Anderson 1984). Nests located in the more densely populated areas of the colonies are more sheltered from predation more than those at the periphery (Wittenberger and Hunt 1985). In the context of the relationship nest density and predation, the central – periphery distribution hypothesis was first proposed by Coulson (1968) in his study of colony of Kittiwakes (*Rissa tridactyla*), where he found birds breeding in the central area were of better quality and had higher reproductive success than those nesting in the periphery. Moreover subsequent studies showed that this population is regulated by the availability of central sites (Porter and Coulson 1987) and that birds breeding in the centre have a higher survival rate. (Aebischer and Coulson 1990). The variation in survival arises because central individuals are less accessible to predators (Hamilton 1971; Vine 1971). Central – Periphery distribution hypothesis is generally accepted explanation for nest dispersion patterns in sea bird colonies (Wittenberger and Hunt 1985; Furness and Monaghan 1987; Kharitonov and Sigel- Causey 1988). However there are some examples where this hypothesis is not fulfilled. Ryder and Ryder (1981) found a colony of ring billed gulls (*Larus delawarensis*) in which there was no variation in reproductive success between central and peripheral areas, while in another colony, Pugesek and Diem (1983) observed that reproductive success were determined by different spatial distributional of age groups. Scolaro et al (1996), in a study on a colony of the South American tern (*Sterna hirundinacea*), found that birds nest site selection is at first random and then uniform but not in the central – periphery pattern. In a study on behavior of Kittiwake recruits in a colony in North shields, Porter (1990) found that first time breeders prefer more densely populated sites, with poorer quality birds being regulated to peripheral zones.

Danchin et al (1991) reported that recruits are directly attracted by successful sites and they visit these sites during the prospecting season. It's widely assumed that edge or fringe nesters should have a lower breeding success compared to central nesters (Wittenberger and Hunt 1985). Several authors have reported that edge or fringe nesters show higher levels of failure than more central nesters and that the centre advantage increases as colony size increases (Rukk 1968; Brown and Brown 1987, Spear 1983). Furthermore, several studies have shown preference by males for establishing territories with in the centre of colonies (Kittiwake, *Rissa tridactyla*, Coulson 1964; Least terns, Burger 1988).

The heronries play a vital role in the life cycle of the birds of family Ardeidae, Ciconiidae, Threskiornithidae and Phalacrocoracidae. In mixed species heronries, such diverse groups congregate in large numbers to breed and raise their progeny. Different species occupy certain space in the heronry at certain times. Strong site fidelity has been observed among birds as this is advantageous to them. As the birds become familiar with the area, it enhances their foraging success, predator avoidance, defense and other behaviours, which contribute to reproduction performance (Newton and Wyllie 1992). This chapter documents about the patterns of nest spacing and the factors that determine such patterns. Nest tree preference, species association and disassociation patterns, species preference of nest trees and vertical stratification of nesting species are dealt in detail in this chapter.

5.2 Methods

Field methods: With such a large congregation of breeding birds in a small area it would be interesting to learn how these birds share the available limited resources. Parameters such as type of materials used for nesting, nest height in a tree, type of branch in the tree used for nesting, direction of the nest, distance from the nearby foraging areas and food habits were collected to study the resource partitioning among breeding birds in the heronry. Nest constituents were visually identified and types of tree species used for nesting were noted. Since the average height of the trees in the heronry are around 5-6 m (personal observation), nest height was approximately estimated using one meter graded pole (Datta and Pal 1993). In case of exceptionally tall trees the tree height was visually estimated. Nearest neighbour distance was measured both vertically and horizontally using a measuring tape for all the species. To study the species association dissociation patterns all species in the selected nest tree will be recorded. The heronry census was carried out in the last week of August, just after the hatching process of all the birds were over. Since the nests of different bird species are not uniformly distributed in this heronry, sample count of nests would give biased information on the total number of breeding birds. Hence, a total count of nest trees was carried out in the heronry. The entire nesting colony was subdivided into smaller subunits and based on the natural boundaries. All the trees in the subunits were then marked numerically in increasing order by paint. Parameters like, tree species, tree height, Girth at breast height (GBH), species nesting on the tree, no of nests, nest height were recorded. Nest height and tree height were visually estimated. GBH was measured with an inch tape. The nest of the bird species was identified by looking at the species guarding the nets and during the absence of both the parents, the nest design and nest materials were used to identify the species nesting. To determine the nest location in the trees, the entire tree height was divided in to five strata i.e., Upper canopy, upper middle, lower middle, lower and lowest canopy.

Analytical methods:

Relationship between tree height & no. of nests:

Since the scatter plot showed a non-linear association, non-linear regression was performed. The relationship was found to follow quadratic model. ($r = 0.54$, F Significance < 0.01).

Species preference of nesting trees:

We developed a simple and straightforward preference index (PI) for investigating the nesting tree preference by the water birds.

PI = -1 * [1 – F (observed) / F (expected)]

Where

F (obs) = Observed number of nests on the given tree species

F (exp) = Expected number of nests calculated as the relative proportion of the number of tree species

The final value ranges from $-\infty$ to $+\infty$, where 0 refers to random selection. Increasing values on positive scale indicate preference while the negative scores point to avoidance. For the sake of clarity, we predefine the index value of 1 to ≥ 3 as zone of preference and -1 to ≤ -3 as zone of avoidance. The scores ranging between -1 to + 1 are treated as evidence for the random choice of the nesting tree.

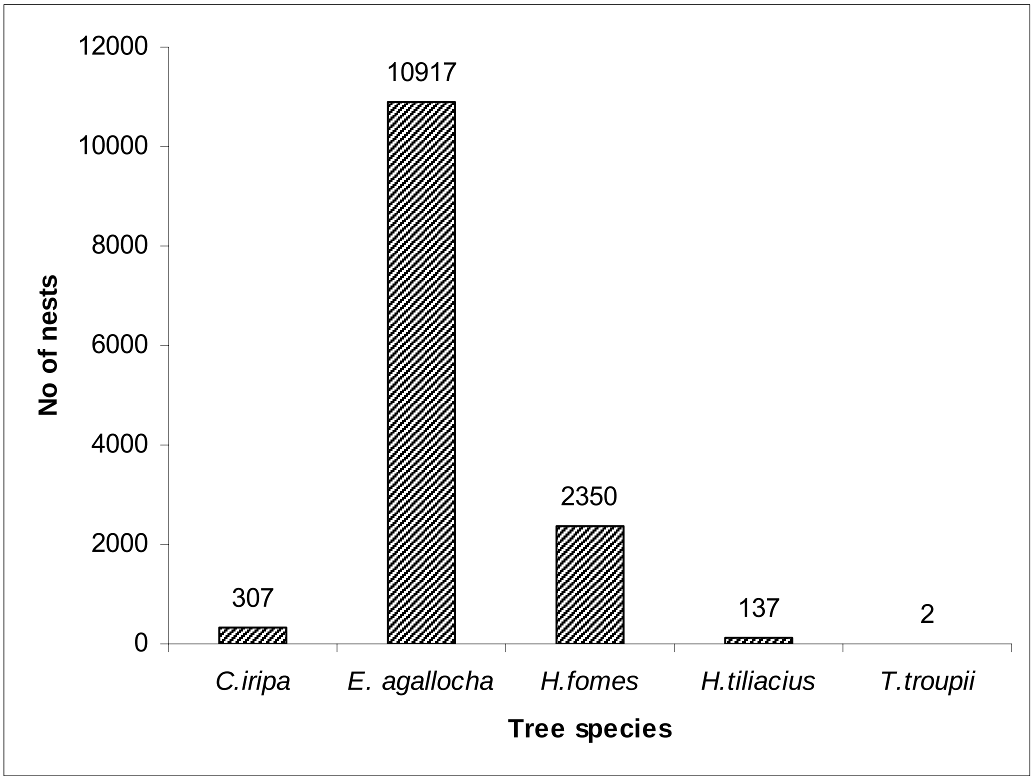
Spatial association / co-occurrence of nesting species in the Heronry: Pearson's Chi-square Statistic # $P > 0.05$ (indicating spatial independence of nests) was carried out to understand the association between nesting species in the heronry.

All statistical analysis was carried out using the statistical package SPSS 8.0.

5.3 Results

5.3.1. Nest tree usage: Birds used five species of mangrove trees; *Excoecaria agallocha* (Guan), *Heritiera fomes* (Bada Sundari), *Cynometra iripa* (Singada), *Hibiscus tiliaceus* (Bania), *Tamarix troupii* (Jagula) for nesting in the heronry. A total of 3843 nest trees were counted inside the heronry. A majority of 77.9% nest trees were *Excoecaria agallocha* followed by *Heritiera fomes* (18.7%), *Cynometra iripa* (2.8%), *Hibiscus tiliaceus*(0.9%) and only one tree of *Tamarix troupii* was used for nesting Maximum numbers of 79.6% nests were recorded in *Excoecaria agallocha* followed by *Heritiera fomes* (17.4%), *Cynometra iripa* (2.2%), *Hibiscus tiliaceus*(0.9%) and only two nests were found on *Tamarix troupii* (Fig. 5.1).

Fig.5.1. Number of nest w.r.to tree species. *Excoecaria agallocha* is the most abundant tree species in the heronry and maximum nets were recorded in this tree species.



5.3.2. Tree composition in the Heronry: Although *E. agallocha* was the most numerous in the heronry, *H. fomes* was found to be the tallest and stoutest tree species in the heronry (Fig 5.2a & 5.2b). Asian Openbill nests extensively on *E. agallocha* trees and most of these trees are located in the centre of the heronry. Continued nesting of Openbill has damaged the top portions of the trees resulting in a stunted growth of *E. agallocha* in the heronry. This in turn has given a saucer shape to the heronry.

Fig 5.2(a) Relationship between tree species and GBH.

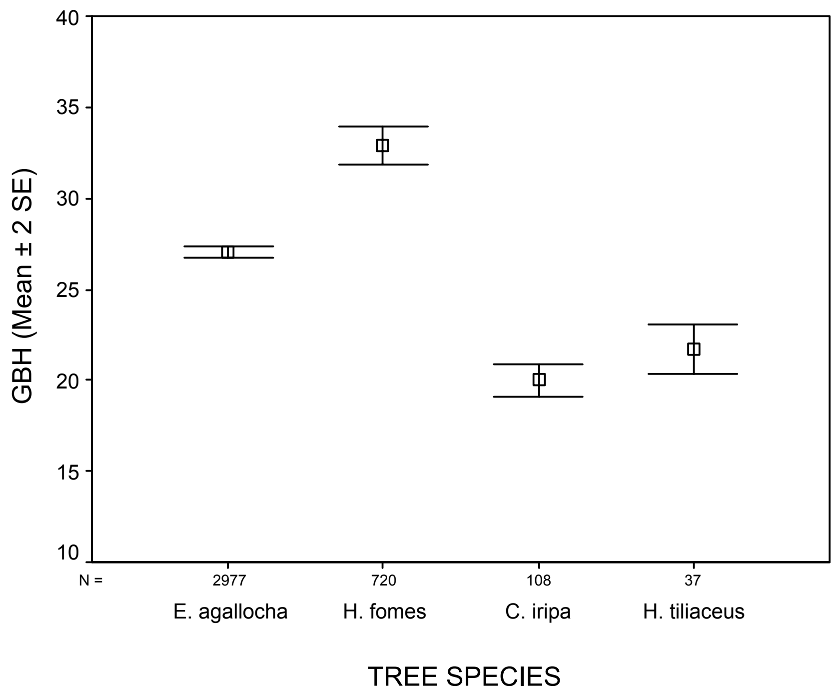
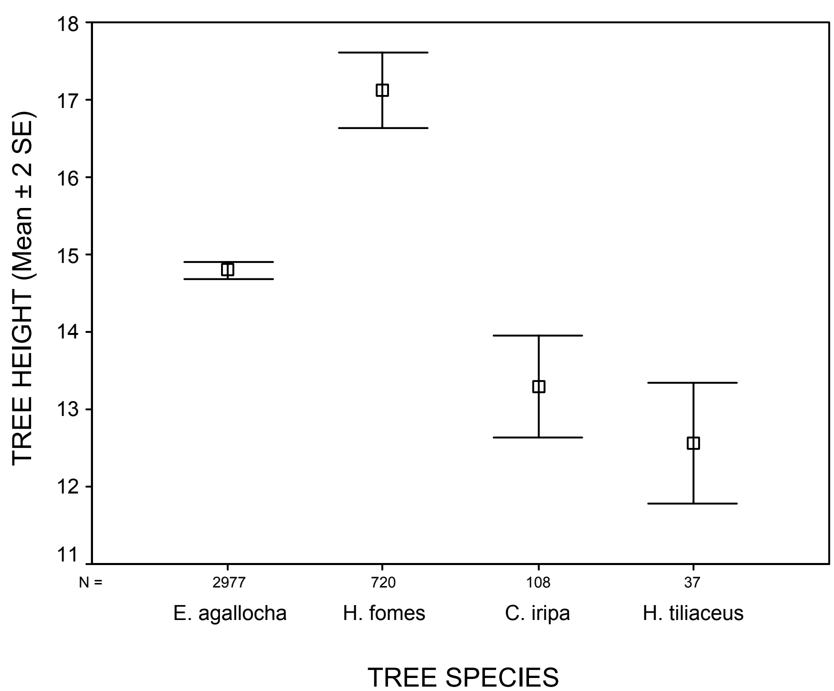


Fig 5.2(b) Relationship between tree species and tree height.



5.3.3. Relationship between tree height/ GBH & no. of nests: The relationship was found to follow the quadratic model which means that the number of nests increases with increasing GBH/tree height up to a certain value after which it starts to decline. This is because the tall and old growth trees occupy the periphery of the heronry but the water birds prefer the interior trees for nesting which are shorter and thinner compared to the peripheral ones (5.3a and 5.3b).

Fig 5.3 (a). Relationship between tree height and no of nests

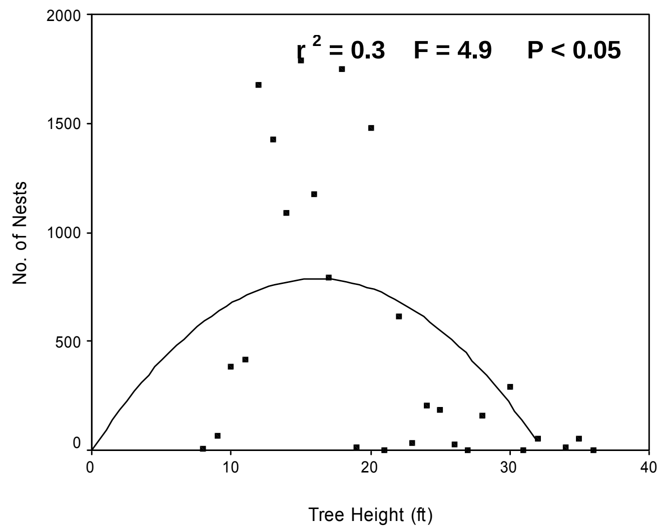
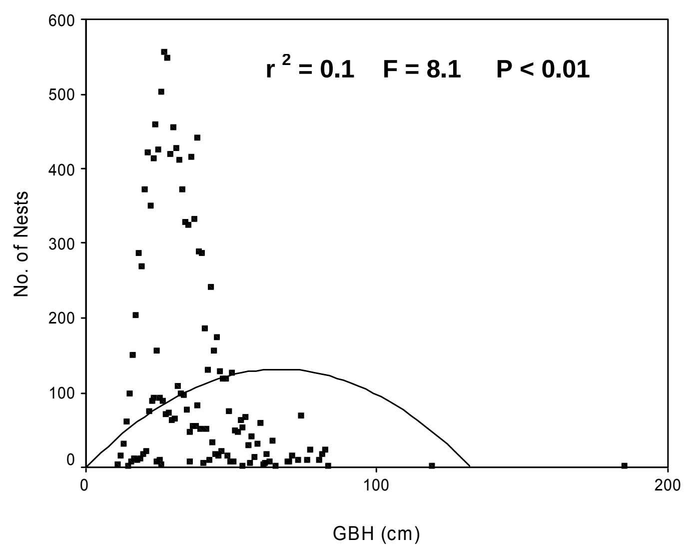


Fig 5.3(b).



5.3.4. Species wise nest height and nest location in the Heronry: Oriental darter, Grey heron and Purple heron showed a higher nest height compared to other species since they preferred the tall *Heritiera fomes* to nest (Fig 5.4a). Asian Openbill storks showed affinity to nest in the top canopy and their mean nest height was 14 ft. They nest extensively on *Excoecaria aggallocha*, which had a mean tree height of 14.5 ft. Most of the nesting species showed affinities to nest in the upper and upper middle canopy; however White ibis and Night herons showed preference for nesting in the lower middle canopy also (Fig 5.4b). None of the species showed evidence to nest in the lower and lowest canopy since the branching of the trees started only from the lower middle canopy.

Fig 5.4 (a). Mean nest height of nesting species

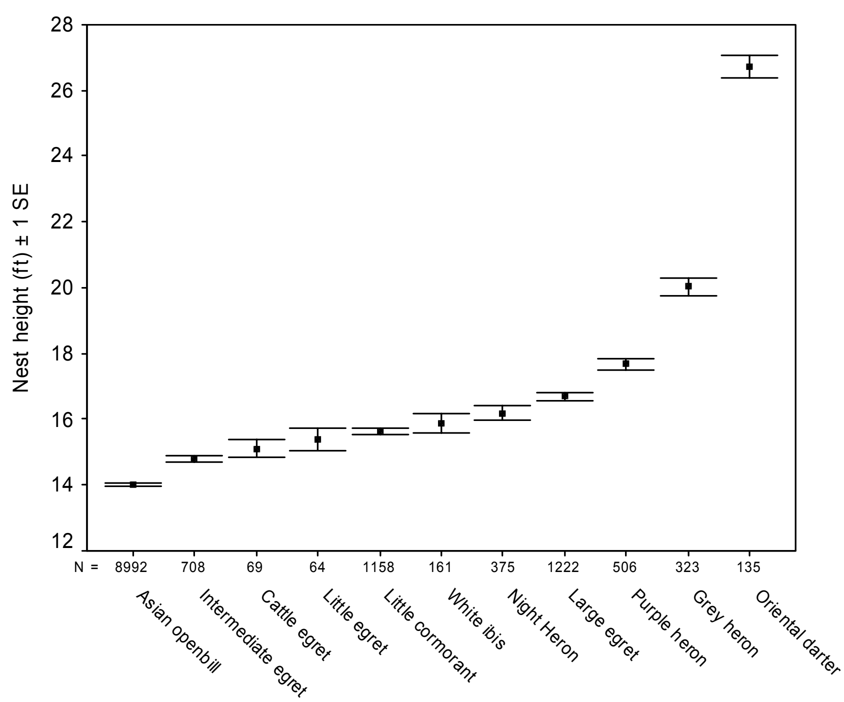
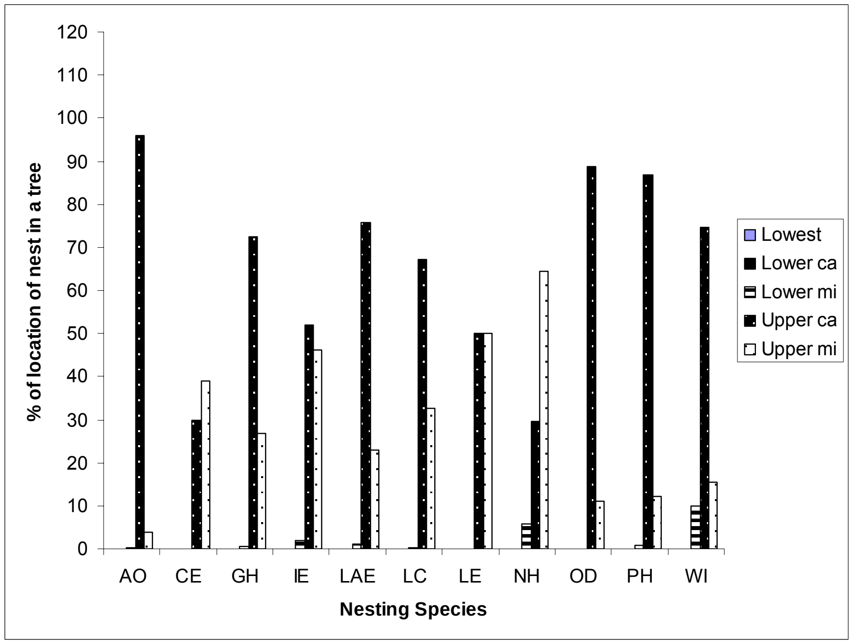


Fig 5.4 (b) Nest location in the nesting trees



5.3.5. Spatial association / co-occurrence of nesting species in the heronry: White Ibis showed strong dissociation with other colonial species except for Large and Intermediate egrets and tends to nest forming sub colonies inside the heronry. Grey heron and Purple heron showed lesser evidence of nesting together and similar trend was also seen between Night heron and cattle egret. Darters also showed dissociation with Little cormorants, Intermediate, Little and Cattle egrets (Table 5.1).

5.3.6. Species preference of nesting trees: Asian Openbill, Little cormorant, White ibis, Little egret, Cattle egrets showed a preference to nest in *Excoecaria agallocha*, where as Darter, Grey heron, purple heron and night herons showed a preference to nest in *Heritiera fomes*. White Ibis, Little cormorant, Darter, Intermediate egret, little egret and cattle egret tends to avoid nesting in *Hibiscus tiliaceus*. (Fig 5.5 a, b and c)

Fig 5.5 (a). Nest tree preference of Openbill, Little cormorant, White ibis and Darter. Darter showed a strong preference to nest in *Heritiera fomes*.

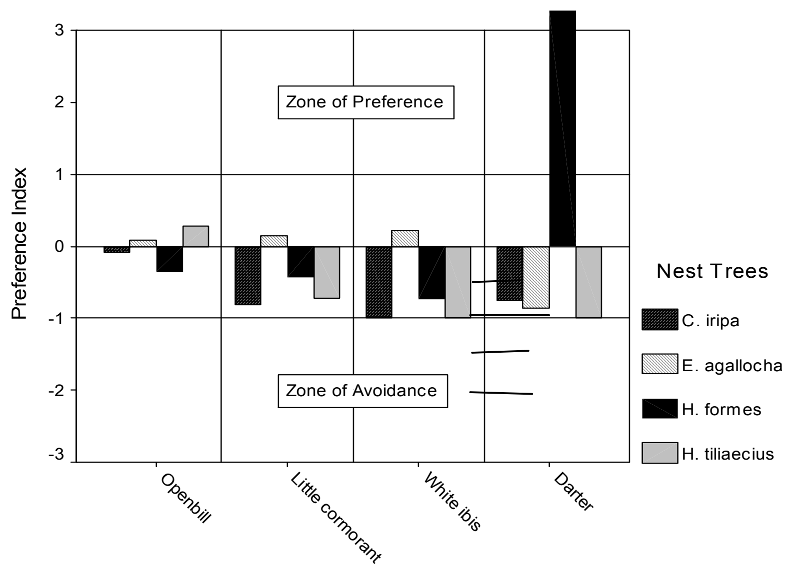


Fig 5.5 (b). Nest tree preference of Large egret, Intermediate egret, Little egret, Cattle egret.

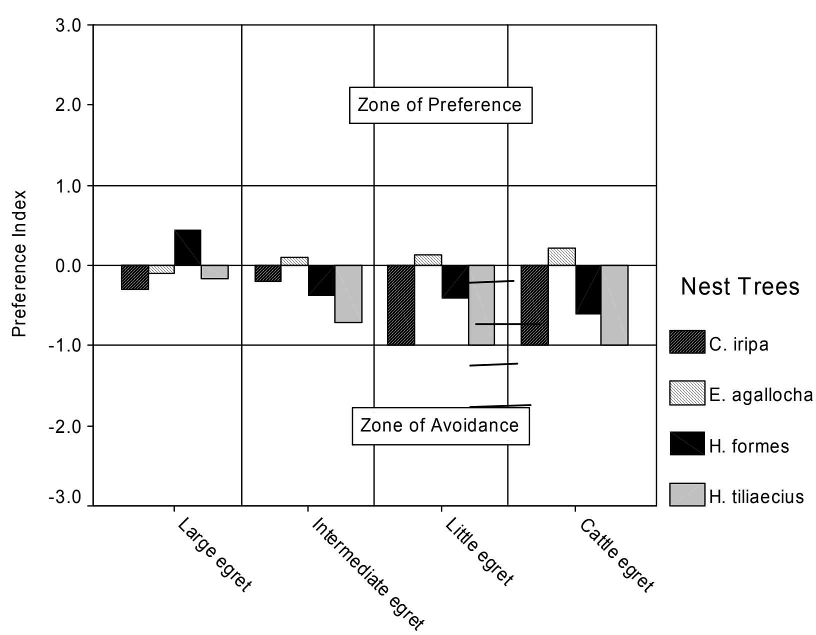
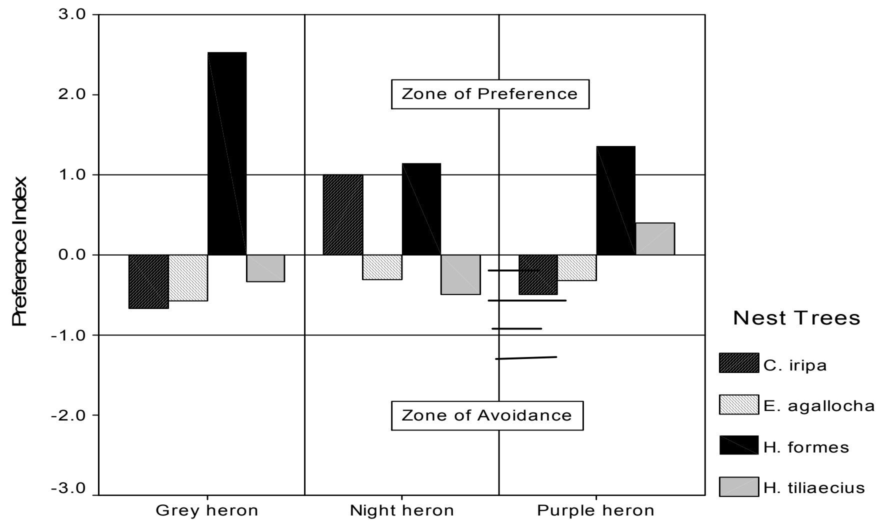


Fig 5.5 (c). Nest tree preference of Grey heron, Purple heron and Night heron. All the three species showed a strong preference of *Heritiera fomes*.



Competition for space in waterbird colonies is known to be mitigated through habitat partitioning. Both vertical and horizontal associations among the nesting waterbirds in the heronry were studied. It was observed that Asian Openbill *(Anastomus oscitans)*, Large egret *(Ardea alba)*, Intermediate egret *(Egretta intermedia),* Little cormorant *(Phalacrocorax niger)*, and Little egret *(Egretta garzetta)* were associated more frequently than they would be expected at random. There was a significant avoidance trend between Grey *(Ardea cinerea)* and Purple *(Ardea purpurea)* herons, and between Darter *(Anhinga melanogaster)* and Asian Openbill. Interestingly, Black-headed ibis *(Threskiornis melanocephalus)* was observed to nest away from most of the species within the heronry forming sub-colonies on its own.

Results of our analysis on vertical alignment of nests did not support the body mass-nest height hypothesis which postulated a direct positive correlation between body weight and nest height among colonial waterbirds (Fig.5.6). There was a significant radial zonation of species in the heronry with Asian Openbill storks preferring the central portion of the heronry (KW $\chi 2=8.54$, $P<0.05$) whereas Darter and Grey heron nests were observed more towards the periphery of the heronry (KW $\chi 2=6.40$, $P<0.05$) (Fig.5.7). On the other hand, nests of Little egret (KW $\chi 2=11.11$, $P<0.05$), Purple heron (KW $\chi 2=11.53$, $P<0.05$) and Night heron *Nycticorax nycticorax* (KW $\chi 2=10.61$, $P<0.05$) were found to have clumped distribution being restricted to select blocks of the heronry (Fig.5.8).

Fig.5.6 Body mass Vs Nest height:

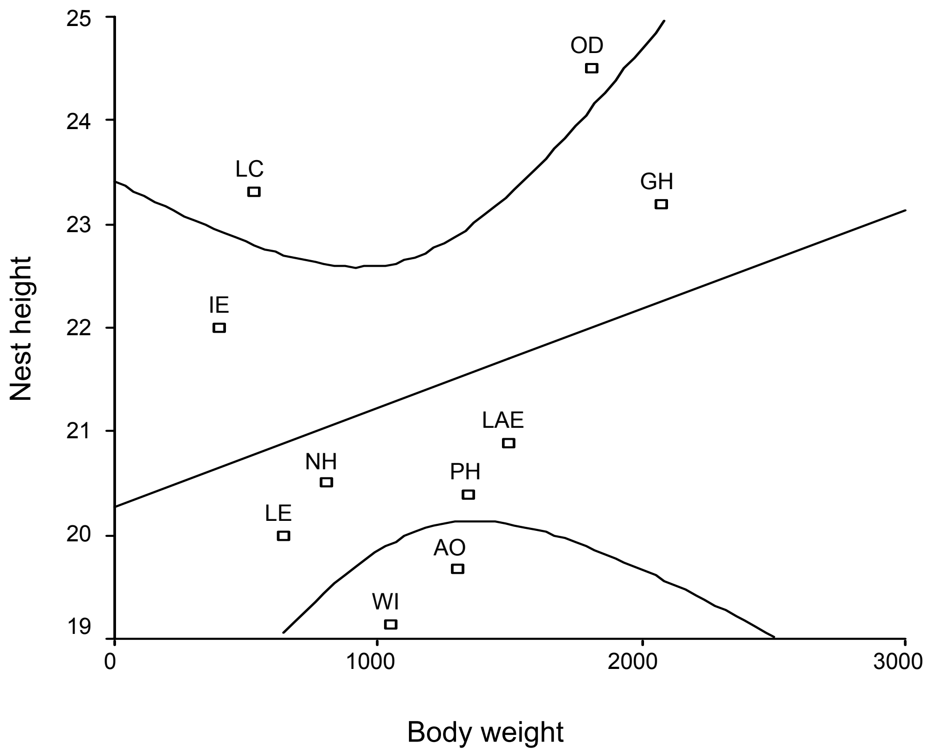


Fig.5.7. Radial distribution of nests

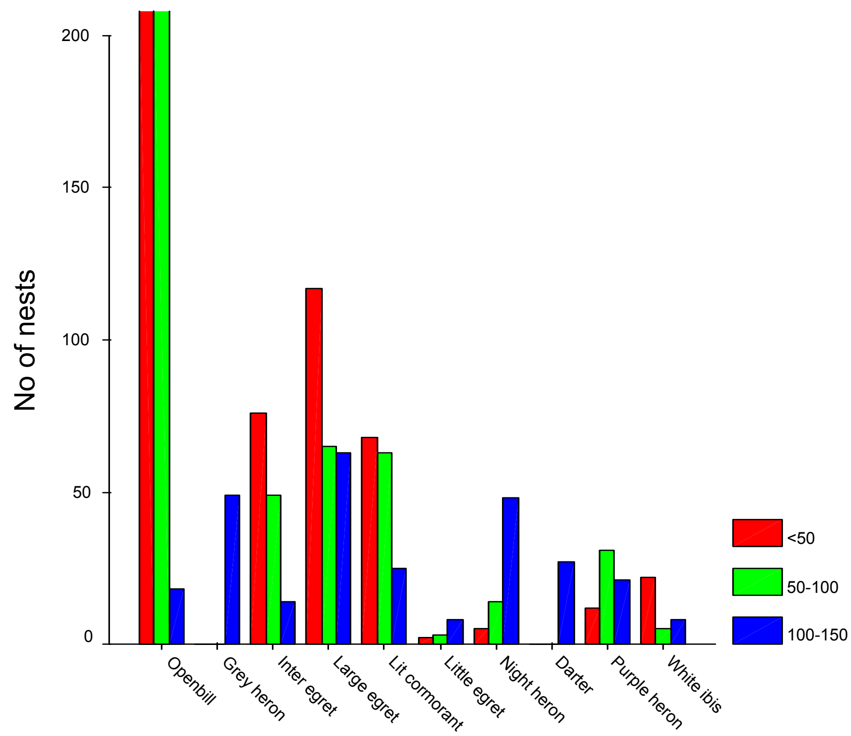


Fig.5.8 Sector wise distribution of nests

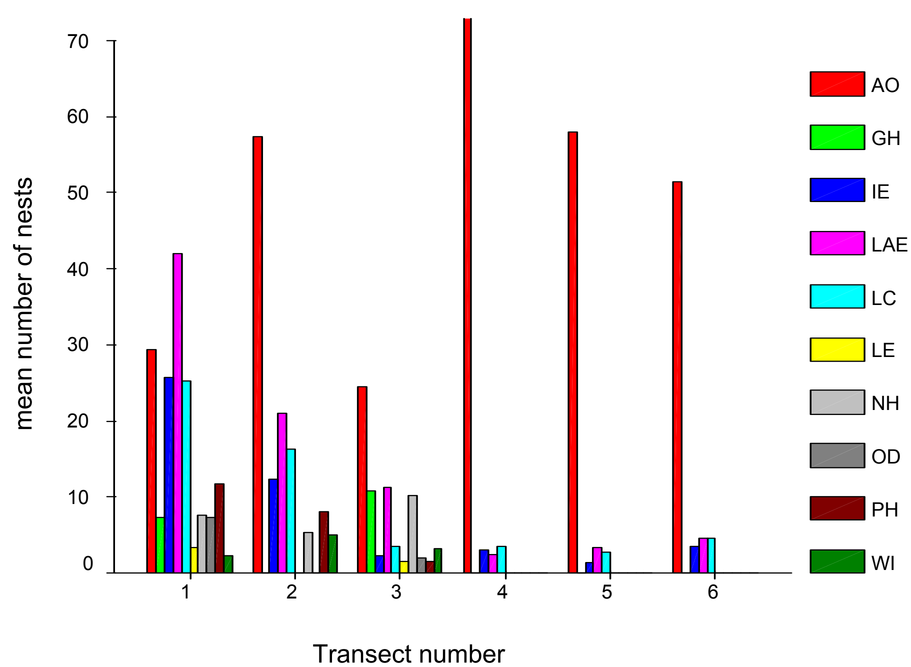


Table.5.1 Spatial association / co-occurrence of nesting species in the heronry: Pearson's Chi-square Statistic # P > 0.05 (indicating spatial independence of nests)

Species	Asian Openbill	Little Cormorant	White Ibis	Oriental Darter	Large Egret	Intermediate Egret	Little Egret	Cattle Egret	Grey Heron	Purple Heron
Asian Openbill										
Little Cormorant	444.1 P<0.0001									
White Ibis	140.6 P = 0.753	182.1 P<0.0001								
Oriental Darter	204.4 P<0.0001	57.8 P = 0.886	0.673 P > 0.999							
Large Egret	1761.3 P<0.0001	1236.3 P<0.0001	378.8 P < 0.0001	205.3 P<0.0001						
Intermediate Egret	585.1 P<0.0001	1441.2 P<0.0001	197.8 P< 0.0001	60 P = 0.114	710.2 P< 0.0001					
Little Egret	56.8 P = 0.008	424.9 P<0.0001	0.710 P > 0.999	0.886 P>0.999	199.7 P< 0.0001	195.7 P< 0.0001				
Cattle Egret	240.5 P<0.0001	921.3 P<0.0001	11.6 P = 0.995	28.3 P = 0.24	239.1 P< 0.0001	840.1 P< 0.0001	23.2 P=0.001			
Grey Heron	723.9 P<0.0001	81.8 P = 0.009	6.15 P >0.999	5417.6 P<0.0001	267.4 P< 0.0001	118.1 P< 0.0001	10.8 P = 0.541	20.1 P=0.322		
Purple Heron	628.0 P<0.0001	987.9 P<0.0001	5.47 P> 0.999	157 P< 0.0001	1108.5 P< 0.0001	297 P< 0.0001	126.1 P< 0.0001	156.2 P< 0.0001	59.8 P=0.118	
Night Heron	278.3 P<0.0001	648.1 P<0.0001	10.5 P > 0.999	4529.1 P< 0.0001	1052 P< 0.0001	116.8 P< 0.0001	124.8 P<0.0001	31.6 P = 0.06	4911.1 P< 0.0001	1341.4 P< 0.0001

5.4 Discussion

Resource partitioning studies generally deal with food (Culver 1994 and Kaufmann 1974), but the partitioning of space to avoid competition. Actually aggression is the most precise mechanism for such partitioning. Since large species largely win over smaller species by occupying the preferred nest sites independent of their arrival and settlement patterns of the birds to the heronry (Schoener 1974). In heronries with mixed tree species, the larger species tend to select particular types of vegetation and while in homogenous vegetation heronries with no physical difference, species might divide the available space among themselves. The Darters and Grey herons were the first to arrive at the heronry and they chose to nest only in the peripheral tall *Heritiera fomes* trees and the Asian Openbill storks which are the dominant nesting birds in the heronry chose to nest only in the central location of the heronry. The Oriental white ibis, though arrives last in the heronry, they also tend to nest in the central location by displacing already established nests of small birds like large egrets, intermediate egrets and little egrets. One other major factor to partition the space is by nest tree preference. The oriental darters, Grey herons, Purple heron and Night herons showed a strong preference to the *Heritiera fomes* trees. Night herons also showed preference to the *Cynometra iripa* trees. Night herons are usually shy species and love to nest in thick canopy trees with plenty of shade and this might be the reason for them to choose the peripheral location of the heronry dominated by *Heritiera fomes* and *Cynometra iripa*. Species like White Ibis, Asian Openbill, little cormorant, Intermediate egret and Cattle egret showed a strong preference to nest in the *Excoecaria agallocha* trees. Asian Openbill stork have a propensity to clip the apical leaves while nest building and renovation, which is why Openbill prefer to nest in the small and tender *Excoecaria agallocha* trees whose apical leaves could be easily clipped by Openbill in comparison to the hard and sturdy *Heritiera fomes* and *Cynometra iripa* trees. White ibis tend to form subcolonies i.e. many individuals group together and occupy an entire tree and nest either vertically or horizontally with all the nests touching each other. *Excoecaria agallocha* trees structures are perfect for supporting these sub colonies and this would be the reason white ibis showing preference to nest in *Excoecaria agallocha* trees. Certain species showed strong association patterns and whereas certain species tend to avoid each other, for example White Ibis showed strong dissociation with other colonial species except for Large and Intermediate egrets and tends to nest forming sub colonies inside the heronry. Grey heron and Purple heron showed lesser evidence of nesting together and similar trend was also seen between Night heron and cattle egret. Darters also showed dissociation with Little cormorants, Intermediate, Little and Cattle egrets. The relationship was found to follow the quadratic model which means that the number of nests increases with increasing GBH/tree height up to a certain value after which it starts to decline. This is because the tall and old growth trees occupy the periphery of the heronry but the water birds prefer the interior trees for nesting which are shorter and thinner compared to the peripheral ones. Oriental darter, Grey heron and Purple heron showed a higher nest height compared to other species since they preferred the tall *Heritiera fomes* to nest. Asian Openbill storks showed affinity to nest in the top canopy and their mean nest height was 14 ft. They nest extensively on *Excoecaria aggallocha*, which had a mean tree height of 14.5 ft. Most of the nesting species showed affinities to nest in the upper and upper middle canopy; however White ibis and Night herons showed preference for nesting in the lower middle canopy also. None of the species showed evidence to nest in the lower and lowest canopy since the branching of the trees started only from the lower middle canopy. Both vertical and horizontal associations among the nesting waterbirds in the heronry were studied. It was observed that Asian openbill *(Anastomus oscitans)*, Large egret *(Ardea alba)*, Intermediate egret *(Egretta intermedia),* Little cormorant *(Phalacrocorax niger)*, and Little egret *(Egretta garzetta)* were associated more frequently than they would be expected at random. There was a significant avoidance trend between Grey *(Ardea cinerea)* and Purple *(Ardea purpurea)* herons, and between Darter *(Anhinga malanogaster)* and Asian Openbill. Interestingly, Black-headed ibis *(Threskiornis melanocephalus)* was observed to nest away from most of the species within the heronry forming sub-colonies on its own.

It has been proposed that within homogenous vegetation, nesting herons align themselves vertically in direct relation to body length, with larger species at higher levels. This was attributed mainly to arrival times and to aggressive dominance by the larger species (Burger 1978, 1982). This pattern has been confirmed in some studies (McCrimmon 1978) but not in others (Burger and Gochfeld 1990), and a large variation exists between colonies, because herons adapt to the available vegetation (Beaver et al, 1980). However results of our analysis on vertical alignment of nests did not support the body mass-nest height hypothesis which postulated a direct positive correlation between body weight and nest height among colonial waterbirds. This observed pattern might be due to two reasons: 1. Occurrence of heterogeneous vegetation which makes different birds chooses different nest trees according to biological requirements and 2. Larger birds might tend to nest lower in the nest tree to conceal their large nests and attain greater protection from the aerial predators.

There was a significant radial zonation of species in the heronry with Asian openbill storks preferring the central portion of the heronry (KW $\chi2=8.54$, $P<0.05$) whereas Darter and Grey heron nests were observed more towards the periphery of the heronry (KW $\chi2=6.40$, $P<0.05$). On the other hand, nests of little egret (KW $\chi2=11.11$, $P<0.05$), Purple heron (KW $\chi2=11.53$, $P<0.05$) and Night heron *Nycticorax nycticorax* (KW $\chi2=10.61$, $P<0.05$) were found to have clumped distribution being restricted to select blocks of the heronry.

5.5 Summary of findings

It was observed that Asian Openbill stork, Large egret, Intermediate egret, little cormorant and little egret were associated more frequently than they would be expected at random. There was a significant avoidance trend between Grey heron and Purple heron, and between Oriental Darter and Asian Openbill stork. Interestingly, White Ibis was observed to nest away from most of the species within the heronry forming sub-colonies on its own. Results of our analysis on vertical alignment of nests did not support the body mass-nest height hypothesis which postulated a direct positive correlation between body weight and nest height among colonial waterbirds. There was a significant radial zonation of species in the heronry with Asian Openbill storks preferring the central portion of the heronry, whereas Oriental Darter and Grey heron nests were observed more towards the periphery of the heronry. On the other hand, nests of little egret, Purple heron and Night heron were found to have clumped distribution being restricted to select blocks of the heronry. These foretold patterns might have been responsible for reducing the interspecific aggression and thereby enhancing the interspecific resource partitioning.

CHAPTER 6

FOOD HABITS AND LAND USE CHANGE AROUND HERONRY

6.1 Introduction

Documenting diet composition and dietary responses to environmental variation yield important knowledge about patterns of resource use. Because food is an essential resource, researchers have often hypothesized that food-niche differentiation is an active target of natural selection. Sympatric species may partition food resources by using different prey types, foraging habitats, foraging methods or foraging times. Partitioning may occur through independent selection of resources or may be determined by active interspecific competition. In many instances, however food may not be a limiting factor and resource use may be opportunistic, with all species tending to exploit the most profitable habitats and locally abundant prey types (Fasola 1994). Documenting intraspecific variation in diet composition in response to environmental changes and documenting differences in diet composition among coexisting species may help identify whether species use the food resources in the area opportunistically or selectively. Combined with data on the foraging habitats such information helps determine the probably range of species' responses to changed environmental conditions. This knowledge in turn enables development of ecological management strategies that accommodates various management actions and sustainable ranges of prey and predator species. Colonial waterbirds are among the most thoroughly studied group of birds. Several studies emphasized the diet and trophic niche variation in different species (Kushlan 1978; Fasola and Ruiz 1996). Moreover literature shows these birds may be useful as biological indicators (Custor and Osborn 1977). Several studies have focused on the dietary habits of different species that feed on similar prey. This approach allows more general discussions on bird ecology relating to aspects of guild structure, trophic niches and resource use. Theoretically, if two species resemble each other too closely in their requirements, one will have more efficient methods of using the necessary resources and ultimately will drive the second to extinction (Gause 1934). In the recent past many field studies have concentrated on documenting differences in resource use between similar species. Schoener (1974) have reviewed many of those studies. The coexistence of the colonial nesting species makes them an interesting group to examine for methods of sharing resources. This chapter quantitatively explores the diet composition- prey types-prey sizes for each species, interspecific and intraspecific variation in diet composition, and discusses the competition avoidance if any between species.

Conversion of Agricultural fields into Aquaculture farms: India has a long coastline of over 7500 km, with numerous brackish water lakes, estuaries, lagoons and backwaters suitable for shrimp farming. Aquaculture underwent rapid growth worldwide between the 1970s and early 1980s, and expanded along the coasts of India during the 1990s. Global aquaculture production has been steadily increasing over the last decade, in a boom reflected in shrimp production figures for India which increased from 0.78 million mt in 1987 to 1.77 million mt in 1996 (126%), with a corresponding increase in value from US$ 0.83 billion to US $ 1. 98 billion (139%) (FAO, 1998). The major states in India where aquaculture is practiced are, in the order of importance: West Bengal, Gujarat, Andhra Pradesh, Maharashtra, Orissa, Kerala and Tamil Nadu. Traditional paddy cum shrimp farming continue to be carried out in West Bengal, Kerala, Karnataka and Goa over about 50 000 ha. The total area under cultivation rose from 65 100 ha in 1990–1991 to 141 837 ha in 1998–1999. The increase in aquaculture in India has brought it into conflict with users of natural aquatic resources, and organizations concerned about its ecological effects. The report of an investigation by the National Environmental Engineering Research Institute (NEERI 1995) of India found that many coastal aquafarms were not scientifically designed and located, resulting in excessive ecological and social damage that far exceeded economic benefits. Damage extended to the spread of brackish water, loss of potable water, loss of traditional fishing grounds for fishermen, and loss of mangrove ecosystems which provide both protection against cyclones and other natural hazards and natural habitat for spawning of natural biota (Reddy 1995). Further, indiscriminate destruction of mangroves resulted in loss of natural breeding grounds for the shrimps themselves. Over the past one decade and a half, agricultural fields are rampantly converted in to aquaculture farms by the traditional farmers to yield quick money. This conversion of land use to other forms does have impact on the birds from the nesting colony that are dependent on these agricultural fields for foraging. In recent years paddy fields in this area are rapidly being converted to shrimp ponds, thus reducing the foraging areas available for the breeding birds. This chapter looks in to how the prey base is affected by aquaculture farms for the Asian openbill stork, which is the most abundant nesting species in the heronry.

6.2 Methods

There are three methods of determining the food of birds quantitatively, by numerical (items of food consumed), volumetric and gravimetric. In addition, Lack (1954) has suggested that the food of birds can be expressed in terms of calories rather than grams. Volumetric methods have been recommended by Beal and McAtee (1912) and Collinge (1927). For this study I have documented by numerical (items of food consumed), volumetric and gravimetric methods for estimation of food. Though examination of whole of the stomach and intestinal tracts would give precise information of the food consumed, I did not follow this method of capture and killing the birds. Rather, I collected the regurgitated food materials from the nestling birds by standing under a nest for a while with a large cloth to collect the regurgitated boluses. The birds regurgitated when alarmed by predators or human beings. Two views are given to explain this behaviour. This regurgitation serves as an antipredatory device to lure away predators by causing them to consume the regurgitation food instead of killing the nestlings (Kushlan 1978). Also, the regurgitation makes nestlings more mobile so that they can easily escape from the predators (Owen 1955; Voisin 1978). Food items were broadly classified e.g. insects, molluscs, fish, amphibians and snakes, lizards, frogs etc. Sizes of all prey items consumed were taken into consideration while analysing the data for differences in food habits.

Land use change impact of prey abundance: Two hundred and seventy two 1m X 1m quadrats were laid in near to aquaculture farms and faraway from aquaculture farms. The quadrats near to aquaculture farm is laid inside the 50 m of radius of the aquaculture farm and the quadrats faraway from the aqualture harms were laid in a distance of at least two kms from a aquaculture farm. At each quadrat number of apple snails (*Pila globosa*) encountered were counted and the dry weight was weighed later in the base camp to determine their biomass. Later, prey item from all the locations of sampling points were averaged to give a mean. The results are expresses as numbers an biomass (g dry weight) of prey items in every transect in the paddy field. Differences between sampling points close to aquaculture farms and faraway from aquaculture farms are assessed using a repeated measures of ANOVA after $\log_e(x\text{-}1)$ transformations.

6.3 Results and discussion

6.3.1 Food habits: A total of 1422 regurgitated samples were collected from the chicks of varying age of all species (Table 6.1). Food habit analysis revealed most species preferred to feed on fish except for Openbill storks for which bulk of the diet of >99% was composed of apple snails (*Pila globosa*).Little egret, Little cormorant and white Ibis had significant proportion of prawns and shrimps in their diet. On couple of instances, little egret’s digits were found in the regurgitated samples of Night heron chicks, suggesting night heron may predate or scavenge on other birds. Water snakes (*Enhydris enhydris*, dog faced water snake) were preferred by Purple heron followed by Night heron, grey heron and little cormorant. Very few insects (mostly water beetle larvae) were found in the diet of white ibis, night heron, intermediate and little egret (Table 6.2, Fig 6.1).

Methods: Any diet study that relies on the analysis of food items after they have entered the digestive tract is affected by differential digestion (Peterson and Bradley 1978). That is the occurrence of some food items may be overestimated if the items are resistant to digestion and stay in the digestive tract for a long time, or conversely the occurrence may be underestimated or missed entirely if the items are easily digestible (Hyslop 1980; Floyd and Jenssen 1984; Briggs et al. 1985). The problem is most acute when it involves relatively small predators that take long time to consume prey (Fairweather and Underwood 1983), but differential digestion may also influence conclusions about predators, such as egrets, that are relatively large compared to their prey. The way in which food samples are collected and the part of the gut from which they come also have an influence and affect comparability between studies. Floyd and Jenssen (1984) examined prey taken from both the stomach and the hind gut of lizards and found a 32% reduction in the number of taxa and 18% reduction in sizes between the two sections. Prey that was under represented in the hind gut was soft-bodied arthropods. Bird regurgitations come from the Oesophagus (crop and proventricus), so this is not likely to be as much of problem in bird studies (Briggs et al. 1985).

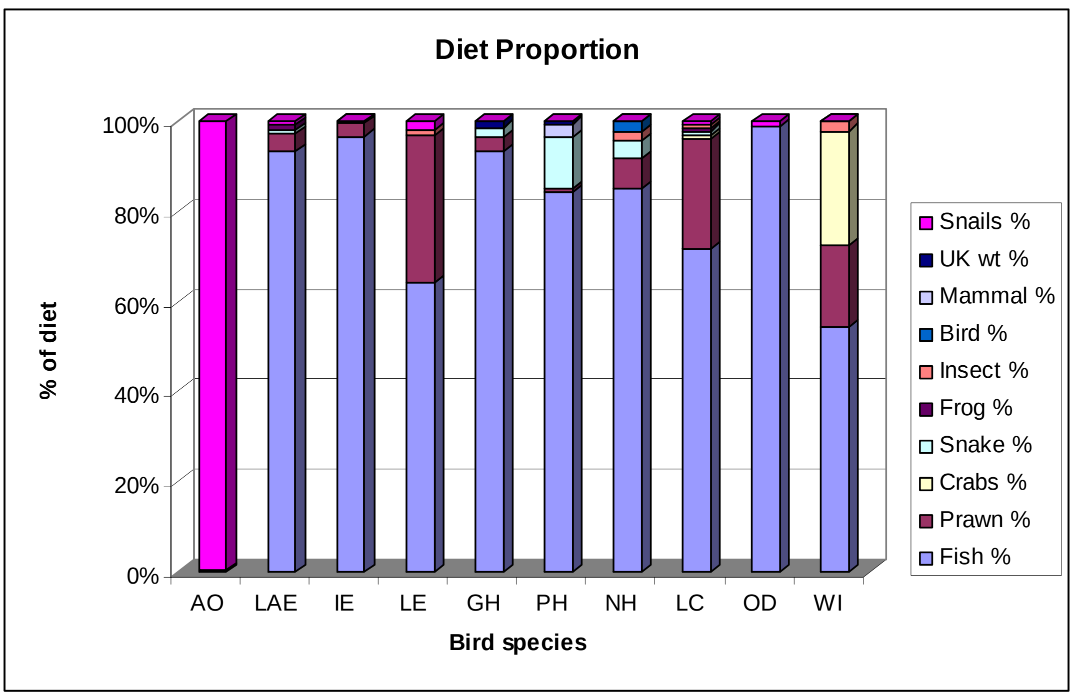
Table.6.1 Number of regurgitated boluses analysed:

Species	**Number of regurgitated boluses**
AO	468
GH	74
IE	95
LAE	223
LC	227
LE	43
NH	41
OD	44
PH	176
WI	31
Total	**1422**

Table 6.2 Diet Proportion of breeding birds in the heronry

	Fish %	Prawn %	Crabs %	Snake %	Frog %	Insect %	Bird %	Mammal %	UK wt %	Snails %
AO	0.11	0.00	0.11	0.22	0.00	0.00	0.00	0.00	0.00	99.78
GH	93.24	3.38	0.00	2.03	0.00	0.00	0.00	0.00	1.35	0.00
IE	96.67	2.98	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00
LAE	93.20	3.96	0.00	0.90	1.12	0.15	0.00	0.00	0.00	0.67
LC	71.71	24.52	0.59	1.03	0.64	0.66	0.00	0.00	0.00	0.85
LE	64.20	32.72	0.00	0.00	0.00	1.23	0.00	0.00	0.00	1.85
NH	84.96	6.91	0.00	3.66	0.00	2.03	2.44	0.00	0.00	0.00
OD	98.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14
PH	84.38	0.85	0.00	11.36	0.00	0.00	0.00	2.84	0.57	0.00
WI	54.30	18.28	25.27	0.00	0.00	2.15	0.00	0.00	0.00	0.00

Fig 6.1 Diet Proportion of breeding birds in the heronry



Asian Openbill storks: It feeds almost entirely on apple snail (*Pila globosa*) with occasional intake of frogs, crabs and large insects del Hoyo et al (1992). With the onset of south west monsoon, the apple snails come out of aestivation after a few showers and are abundantly found in the surrounding paddy fields. Our study results reveal that more than 99% of the diet of the storks comprised on apple snails and matches with other studies conducted elsewhere (Kahl 1971).

Grey heron: The food of this species was entirely animal (Table 6.3). Mammals such as Rats were found in almost one fourth of the entire prey averaging 40% of the weight of each bolus. Estuarine fishes were the dominant in terms of occurrence, proportion of the total bulk prey weight of the boluses in which they occurred (Table 6.3). Estuarine fishes like *Valamugil cunnesius, Lates calcarifer, Elops machanata, Mugil parsia, Polynemus paradiseus, Rhinomugil corsula, Thryssa mystux* were eaten more frequently. Freshwater fishes like *Mystitus vittatus, Punctus sophero, Wallago attu, Channa striatus, Channa striatus* also eaten frequently. Vertebrates appeared in 100% of the boluses (Table 6.3). Mean prey size are shown in Table 6.3. The fishes eaten were species with widely differing sizes producing large confidence intervals around the mean length. A study by Gwiazda R., Amirowicz A (2006) revealed that grey herons had a selective choice of longer fish from those occurring at foraging sites allowed greater reward with roughly unchanged foraging cost. Our results also revealed that they preferred to prey on longer fishes (Table. 6.3) and were predominately feeding on the estuarine fishes.

Table 6.3 Composition of Grey heron boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	26.9	8.6	33.6 ± 29.6
Birds	0	0	0
Snakes			
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Lizards	12.8	8.1	31.0 ± 26.5
Frogs	6.2	7.2	14.4 ± 18.6
Freshwater fish			
Wallago attu	38.5	36.5	53.5 ± 15
Channa striatus	30.3	8.6	38.7 ± 20.6
Channa punctatus	6.1	<0.1	1.5 ± 0.3
Channa orientalis	0	0	0
Clarius batrachus	0	0	0
Mastacembulus paucalus	0	0	0
Punctus sophero	17.2	0.8	28.6 ±26.5
Punctus ticto	0	0	0
Ambypharyngodon mola	0	0	0
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	0	0	0
Mystitus vittatus	33.3	17.7	60.8 ±20.6
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Valamugil cunnesius	24.2	8.2	31.0 ±27.1
Lates calcarifer	18.2	1	30.6 ±36.5
Elops machanata	12.1	0.5	0
Scatophagus argus	3	0	0
Thryssa mystux	3.3	<0.1	0.9
Lutjanus johni	0	0	0
Rhinomugil corsula	3.3	<0.1	5.2
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	6.1	<0.1	0
Cynoglossus lingua	0	0	0
Mugil parsia	18.2	2.5	14.3 ± 17.5
Etroplus suratensis	0	0	0
Trypauchen vagina	12.1	0.5	0
Secutor insidiator	5.2	<0.1	0
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Purple heron: The food of this species was entirely animal (Table 6.4). Mammals were not found in their diet however, 15% of the boluses comprised of water snakes like *Enhydris enhydris* and *Xenochrophis piscator* making up 11 and 7 % of the total bulk weight and averaging 37 and 18% of the weight of the boluses in which they occurred. Fresh water fishes were the dominant in terms of occurrence, proportion of the total bulk prey weight of the boluses in which they occurred (Table 6.3). Freshwater fishes like *Wallago attu, Channa striatus, Mastacembulus paucalus, Punctus sophero, Anabus testudinus, Mystitus vittatus* were eaten frequently. Vertebrates appeared in 100% of the boluses (Table 6.3). Mean prey size are shown in Table 6.13. Its diet consists of fish 5-15 cm long (occasionally up to 55 cm), salamanders, frogs, insects (e.g. beetles, dragonflies, hemiptera and locusts), crustaceans, spiders and molluscs as well as small birds and mammals, snakes and lizards Kushlan and Hancock (2005), Hancock and Kushlan (1984) and del Hoyo et al (1992). Our results revealed that they preferred to prey predominately on the freshwater fishes.

Table 6.4 Composition of Purple heron boluses:

Prey category	Occurrence in Boluses	Proportion of total bulk weight	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Birds	0	0	0
Snakes			
Enhydris enhydris	14.5	11.2	37.2 ± 18.9
Xenochrophis piscator	8.5	6.5	18.4 ± 17.2
Lizards			
Frogs	16.2	0.7	26.8 ±24.8
Freshwater fish			
Wallago attu	41.5	39.6	58.5 ± 14.8
Channa striatus	29.8	7.9	48.2 ± 20.6
Channa punctatus	6.1	<0.1	1.5 ± 0.3
Channa orientalis	0	0	0
Clarius batrachus	0	0	0
Mastacembulus paucalus	0	0	0
Punctus sophero	16.5	4.9	29.6 ± 21.3
Punctus ticto	0	0	0
Ambypharyngodon mola	0	0	0

Prey category	Occurrence in Boluses	Proportion of total bulk weight	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	18.2	1	30.6 ±36.5
Mystitus vittatus	35.8	18.6	58.8 ±25.6
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	0	0	0
Lates calcarifer	21.6	15.2	37.0 ±18.7
Elops machanata	10.2	0.6	0
Scatophagus argus	3	0	0
Thryssa mystux	3.3	<0.1	0.9
Lutjanus johni	0	0	0
Rhinomugil corsula	18.2	2.5	14.3 ± 17.5
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	6.1	<0.1	0
Cynoglossus lingua	0	0	0
Mugil parsia	0	0	0
Etroplus suratensis	0	0	0
Trypauchen vagina	15	11	12.6 ± 7.2
Secutor insidiator	4.7	<0.1	0
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Night heron: The food of this species was entirely animal (Table 6.5). Birds such as little egret hatchlings were found in almost one half of the entire prey averaging 43% of the weight of each bolus. Both fresh water and estuarine fishes were equally dominant in terms of occurrence, proportion of the total bulk prey weight of the boluses in which they occurred (Table 6.5). Estuarine fishes like *Valamugil cunnesius, Lates calcarifer, Elops machanata, Scatophagus argus, Thryssa mystux, Lutjanus johni, Trypauchen vagina, Cynoglossus lingua, Polynemus paradiseus, Muraenesox talabonoides, Etroplus suratensis, Mugil parsia, Polynemus paradiseus, Rhinomugil corsula and Thryssa mystux* were eaten more frequently. Freshwater fishes like *Mystitus vittatus, Punctus sophero, Wallago attu, Channa striatus, Mastacembulus paucalus, Ambypharyngodon mola, Mystitus vittatus, Anabus testudinus, Clarius batrachus, Channa orientalis* were also eaten frequently. Vertebrates appeared in 94% of the boluses and rest 6% of the boluses had invertebrate presence (Table 6.5). Wolfard, J.W and Boag, D.A (1971) study revealed that the night herons fed primarily on fishes when they were available but were quick to take the advantage of concentrations of other potential prey, especially young birds and perhaps mammals and amphibians. Our results also shows that they tend to predate on smaller birds like little egrets. Also, night herons diet analysis revealed that they fed on all type of fishes and showed a wider prey variation of 28 species of fishes in their diet. The night herons do not actively go for prey hunting and are mostly observed feeding on the ground inside the heronry and scavenging on fallen prey items from other species nests. This might be the reason for the occurrence of at least 28 species of fish in their diet.

Table 6.5 Composition of Night heron boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris			
Xenochrophis piscator	0	0	0
Birds	43	8.9	21.6 ± 9.8
Lizards	1.5	0.6	31.6
Frogs	3.3	9.5	24.5 ± 8.6
Freshwater fish			
Wallago attu	0	0	0
Channa striatus	29.6	4.6	34.7 ± 14.3
Channa punctatus	6.5	<0.1	4.2 ± 4.4
Channa orientalis	0	0	0
Clarius batrachus	37.6	32.4	48.5 ± 7.2
Mastacembulus paucalus	0	0	0
Punctus sophero	16.4	0.3	21.5 ± 6.8
Punctus ticto	0	0	0
Ambypharyngodon mola	0	0	0
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	0	0	0
Mystitus vittatus	42.6	2.9	5.9 ±3.2
Amphinius kochia	2	0	0
Sartonia spinigera	3.6	<0.1	1.3
Estuarine fish	0	0	0
Polynemus sexfilis	8.2	0.2	3.3±1.1
Coilia dussumieri	0	0	0
Valamugil cunnesius	22.6	7.6	14.3±3.4
Lates calcarifer	15.6	1	25.6±3.2

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Elops machanata	12.1	0.5	0
Scatophagus argus	3	0	0
Thryssa mystux	3.3	<0.1	0.9
Lutjanus johni	0	0	0
Rhinomugil corsula	8.2	0.3	4.2±4.5
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	3.6	1.2	0
Cynoglossus lingua	0	0	0
Mugil parsia	3.3	9.3	8.5±6.7
Etroplus suratensis	0	0	0
Trypauchen vagina	14.6	2.9	5.9±3.2
Secutor insidiator	3.6	<0.1	0
Mudskipper	0	0	0
Unidentified Insects	6.1	<0.1	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Large egret: The food of this species was entirely composed of vertebrate diet. Frogs appeared in 23% of the boluses and amounted to close to 4% the weight of each bolus. Fishes were the major vertebrate diet and was mostly dominated by preference towards the estuarine fishes like *Valamugil cunnesius, Lates calcarifer, Scatophagus argus, Rhinomugil corsula, Harpodon neherus, Polynemus paradiseus, Cynoglossus lingua, Mugil parsia* *and Trypauchen vagina*. Few freshwater fishes like *Channa striatus, Punctus sophero, Clarius batrachus and Mystitus vittatus* we also eaten (Table 6.6).

Table 6.6 Composition of Large egret boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes			
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	1.5	0.6	31.6
Frogs	23.5	3.2	15.2±5.9
Freshwater fish			
Wallago attu	0	0	0
Channa striatus	41	0.8	21.5±6.3
Channa punctatus	0	0	0
Channa orientalis	0	0	0
Clarius batrachus	85.2	19.6	25.6±4.8
Mastacembulus paucalus			
Punctus sophero	16.4	0.6	4.5±2.6
Punctus ticto	0	0	0
Ambypharyngodon mola	0	0	0
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	0	0	0
Mystitus vittatus	9.6	<0.1	1.6±1.5
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish			
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	43.6	2.8	5.6±3.3
Lates calcarifer	63.5	21.6	21.6±7.5
Elops machanata	0	0	0
Scatophagus argus	16.5	0.3	2.6±2.5
Thryssa mystux	0	0	0
Lutjanus johni	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Rhinomugil corsula	8.6	0.3	2.5±0.8
Harpodon neherus	9.5	<0.1	1.6±1.8
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	3.6	9.6	15.2±5.6
Cynoglossus lingua	3.6	8.5	3.7±6.5
Mugil parsia	16.4	0.3	3.7±6.5
Etroplus suratensis	0	0	0
Trypauchen vagina	3.3	9.3	5.9±3.2
Secutor insidiator	0	0	0
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Intermediate egret: The food of this species was entirely composed of vertebrate diet. Fishes were the major vertebrate diet found in 100% of all the boluses and was mostly dominated by preference towards the freshwater fishes like *Channa striatus, Clarius batrachus, Punctus ticto, Ambypharyngodon mola, Labeo rohita, Cirhinus mrigala, Anabus testudinus and Mystitus vittatus* were eastern mostly***.*** Only two estuarine fishes like *Valamugil cunnesius* and *Trypauchen vagina were* eaten (Table 6.7).

Table 6.7 Composition of Intermediate egret boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	0	0	0
Frogs	0	0	0
Freshwater fish			
Wallago attu	0	0	0
Channa striatus	30.5	8.9	38.6 ± 21.5
Channa punctatus	0	0	0
Channa orientalis	0	0	0
Clarius batrachus	33.2	17.6	55.2 ± 21.3
Mastacembulus paucalus	0	0	0
Punctus sophero	0	0	0
Punctus ticto	24.2	0.6	1.5± 0.8
Ambypharyngodon mola	27.3	3.5	25.6± 23.6
Labeo rohita	12.1	2.6	18.6± 15.9
Cirhinus mrigala	27.6	2	0
Anabus testudinus	6.1	<0.1	0
Mystitus vittatus	6.2	<0.1	0
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	54.5	1.9	2.8± 2.6
Lates calcarifer	0	0	0
Elops machanata	0	0	0
Scatophagus argus	0	0	0
Thryssa mystux	0	0	0
Lutjanus johni	0	0	0
Rhinomugil corsula	0	0	0
Harpodon neherus	0	0	0
Muraenesox	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
talabonoides			
Muraenesox cinereus	0	0	0
Polynemus paradiseus	0	0	0
Cynoglossus lingua	0	0	0
Mugil parsia	0	0	0
Etroplus suratensis	0	0	0
Trypauchen vagina	12.1	0.6	0
Secutor insidiator	0	0	0
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Little egret: The food of this species was almost entirely animal (Table. 6.8). 25% of the bulk prey weight was crustaceans even though such material occurred in 54% of the boluses and averaged 9% of the weight of the boluses in which it occurred. Freshwater fishes were the dominant prey in terms of occurrence, proportion of the total bulk prey weight, and proportion of the weight of the boluses in which they occurred (Table. 6.8). *Mastacembulus paucalus, Punctus sophero, Punctus ticto, Anabus testudinus and Mystitus vittatus* were the major prey items of fresh water fishes found in the diet. *Trypauchen vagina* was the only estuarine fish found in the diet as .0.5% of the bulk prey weight and occurred in 12%of the boluses and averaged neglible amount of weight of the boluses in which they occurred.

Table 6.8 Composition of Little egret boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	0	0	0
Frogs	0	0	0
Freshwater fish			
Wallago attu	0	0	0
Channa striatus	0	0	0
Channa punctatus	0	0	0
Channa orientalis	0	0	0
Clarius batrachus	0	0	0
Mastacembulus paucalus	30.3	8.5	38.9 ± 21.9
Punctus sophero	45.9	45.6	62.9 ± 18.0
Punctus ticto	25.6	8.9	32.6±27.0
Ambypharyngodon mola	3	0	0
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	27.8	2.6	1.5±0.6
Mystitus vittatus	32.6	2.8	14.6±12.9
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	0	0	0
Lates calcarifer	0	0	0
Elops machanata	0	0	0
Scatophagus argus	0	0	0
Thryssa mystux	0	0	0
Lutjanus johni	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Rhinomugil corsula	0	0	0
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	0	0	0
Cynoglossus lingua	0	0	0
Mugil parsia	0	0	0
Etroplus suratensis	0	0	0
Trypauchen vagina	12.1	0.5	0
Secutor insidiator	0	0	0
Prawns	54.6	25	8.5±5.3
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

White Ibis: More than half of the boluses from White ibis contained vegetable matter, but this only amounted to 9 to 10% of the total bulk prey weight or the weight of the boluses in which it occurred. This species had a large proportion of its prey made up of insects (38% of the total bulk prey weight); those averaged 20% of the weight of the boluses in which they were found (Table 6.9). The most common estuarine fish was the *Trypauchen vagina*, which occurred in the 6% of the boluses followed by *Lates calcarifer* which occurred in 6% of the total bulk prey weight).

Table 6.9 Composition of White ibis boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	0	0	0
Frogs	0	0	0
Freshwater fish			
Wallago attu	0	0	0
Channa striatus	41.6	9.8	21.5±9.6
Channa punctatus	0	0	0
Channa orientalis	0	0	0
Clarius batrachus	0	0	0
Mastacembulus paucalus	0	0	0
Punctus sophero	0	0	0
Punctus ticto	0	0	0
Ambypharyngodon mola	0	0	0
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	0	0	0
Mystitus vittatus	0	0	0
Amphinius kochia	0	0	0
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	0	0	0
Lates calcarifer	6.7	5.8	8.6±2.6
Elops machanata	0	0	0
Scatophagus argus	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Thryssa mystux	0	0	0
Lutjanus johni	0	0	0
Rhinomugil corsula	0	0	0
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	0	0	0
Cynoglossus lingua	0	0	0
Mugil parsia	0	0	0
Etroplus suratensis	0	0	0
Trypauchen vagina	16.4	0.3	3.9±4.9
Secutor insidiator	0	0	0
Mudskipper	0	0	0
Crabs	42.6	2.5	37.6±5.8
Unidentified Insects	85.2	38.6	21.6±6.8
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	54.3	2.5	8.6±5.9

Little cormorant: More than 75% of the boluses from little cormorants contained prawns and amounted to 23% of the total bulk prey weight or of the weight of the boluses in which it occurred. This species had the large proportion of its prey made up of vertebrates and the most common of them were freshwater fishes like *Wallago attu, Channa striatus, Punctus sophero, Punctus ticto, Ambypharyngodon mola, Anabus testudinus, Mystitus vittatus and Amphinius kochia*. *Anabus testudinus* were found in the 60% o the boluses, comprising 5% of the total bulk prey weight and averaging 15% of the weight of the boluses in which they were found (Table 6.10).

Table 6.10 Composition of Little cormorant boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	0	0	0
Frogs	0	0	0
Freshwater fish			
Wallago attu	26.8	2.5	23.6 ± 7.4
Channa striatus	41	9.3	52.6 ± 32.5
Channa punctatus	9.8	<0.1	1.5±1.3
Channa orientalis	0	0	0
Clarius batrachus	0	0	0
Mastacembulus paucalus	0	0	0
Punctus sophero	41.2	9.6	21.6 ± 9.3
Punctus ticto	25.3	3.6	15.6±6.5
Ambypharyngodon mola	8.6	0.6	4.6±4.8
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	60.5	5.6	14.3±3.6
Mystitus vittatus	15.6	2.5	8.6±1.5
Amphinius kochia	8.6	0.3	4.6±2.1
Sartonia spinigera	0	0	0
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	0	0	0
Lates calcarifer	0	0	0
Elops machanata	0	0	0
Scatophagus argus	0	0	0
Thryssa mystux	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Lutjanus johni	0	0	0
Rhinomugil corsula	0	0	0
Harpodon neherus	0	0	0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	0	0	0
Cynoglossus lingua	0	0	0
Mugil parsia	0	0	0
Etroplus suratensis	0	0	0
Trypauchen vagina	0	0	0
Secutor insidiator	0	0	0
Mudskipper	0	0	0
Prawns	75.4	23.3	37.8 ± 6.8
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Oriental darter: The food of this species was almost entirely composed of fishes. 90% of the boluses contained estuarine fishes with rest 10% were composed of freshwater fishes. *Channa striatus* and *Punctus sophero* occurred in 30% of the boluses and averaged 9 and 15% respectively of the weight of the boluses in which it occurred. *Lates calcarifer, Elops machanata, Scatophagus argus, Rhinomugil corsula, Harpodon neherus, Polynemus paradiseus, Cynoglossus lingua* and *Mugil parsia* were the dominant estuarine fishes which were found in the diet of the oriental darters (Table 6.11).

Table 6.11 Composition of Oriental darter boluses

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Mammals	0	0	0
Snakes	0	0	0
Enhydris enhydris	0	0	0
Xenochrophis piscator	0	0	0
Birds	0	0	0
Lizards	0	0	0
Frogs	0	0	0
Freshwater fish			
Wallago attu			
Channa striatus	30.5	8.6	35.6±24.2
Channa punctatus			
Channa orientalis			
Clarius batrachus			
Mastacembulus paucalus			
Punctus sophero	32.6	15.6	56.3±21.6
Punctus ticto	4.2	<0.1	0
Ambypharyngodon mola	8.2	4.2	4.2 ± 2.3
Labeo rohita	0	0	0
Cirhinus mrigala	0	0	0
Anabus testudinus	6.1	<0.1	0
Mystitus vittatus	2.3	<0.1	0
Amphinius kochia	11.3	5.6	4.3 ±1.0
Sartonia spinigera	3.2	<0.1	0.5
Estuarine fish	0	0	0
Polynemus sexfilis	0	0	0
Coilia dussumieri	0	0	0
Valamugil cunnesius	0	0	0

Prey category	Occurrence in Boluses %	Proportion of total bulk weight %	Mean proportion of bolus weight (where prey occurs % ± 95% CI)
Lates calcarifer	25.6	3.8	27.6±25.6
Elops machanata	18.5	1.6	30.2±35.8
Scatophagus argus			
Thryssa mystux	0	0	0
Lutjanus johni	0	0	0
Rhinomugil corsula	38.6	2.9	19.6±14.4
Harpodon neherus	28.9	2.9	27.2±25.0
Muraenesox talabonoides	0	0	0
Muraenesox cinereus	0	0	0
Polynemus paradiseus	18.6	2.5	1.6±14.9
Cynoglossus lingua	12.6	2.5	18.6±14.6
Mugil parsia	32.6	15.6	44.3±25.6
Etroplus suratensis	0	0	0
Trypauchen vagina	3.2	<0.1	5.6
Secutor insidiator	0	0	0
Mudskipper	0	0	0
Unidentified Insects	0	0	0
Hymenoptera	0	0	0
Coleoptera	0	0	0
Lepidoptera	0	0	0
Spiders	0	0	0
All Invertebrates	0	0	0
Vegetable	0	0	0

Interspecific comparison: The range of prey items by each species was more or less similar except for Asian Openbill storks which mostly fed on *Pila globosa* and White ibis which mostly fed on Insects, earthworm and water beetle larvae. Night herons showed a wider prey variation, total prey from 28 species whereas Asian Openbill storks fed selectively only on *Pila globosa* and boluses had only 2 prey items. Large egret and Intermediate egret tended to avoid competition by preferring different species as prey items. Large egrets preferred to eat more estuarine fishes while Intermediate egrets fed mostly on freshwater fishes. Oriental darter and little cormorants ate prey from 7 of the same prey species. In most of the prey categories, there was a significant difference in the size of the prey items consumed, with Oriental darters feeding on larger sized fishes and little cormorants preferring the small sized fishes (Table 6.12). Intermediate egret and little egrets ate prey from 5 of the same prey species. In most of the prey categories, there was a significant difference in the size of the prey items consumed, with Intermediate egrets feeding on larger sized fishes and little egrets preferring the small sized fishes (Table 6.15).

Table. 6.12 Comparison of the mean sizes of prey for Oriental darter and little cormorant:

Taxon	Dimension	Mean Prey size ± 95% CI (mm)	
		Grey heron	Purple heron
Snake	Snout - vent length	0	521.6±25.6
Lizard	Snout - vent length	32.5±5.8	42.1±8.9
Frog	Snout - vent length	0	0
Freshwater fish	Standard length	86.5±5.8*	78.5±3.9*
Estuarine fish	Standard length	95.6±5.2*	85.6±6.8*

*Indicates a significant difference by *t test, P*<0.001

Table. 6.13 Comparison of the mean sizes of prey for Grey heron and Purple heron

Taxon	Dimension	Mean Prey size ± 95% CI (mm)	
		Large egret	Intermediate egret
Snake	Snout - vent length	0	0
Lizard	Snout - vent length	32.5 ± 5.8	0
Frog	Snout - vent length	22.6 ± 5.9	0
Freshwater fish	Standard length	78.9±2.8	65.4±4.8
Estuarine fish	Standard length	87.6±0.8	62.7±8.2

*Indicates a significant difference by *t test, P*<0.001

Table. 6.14 Comparison of the mean sizes of prey for large egret and Intermediate egret

Taxon	Dimension	Mean Prey size ± 95% CI (mm)	
		Oriental darter	Little cormorant
Snake	Snout - vent length	0	0
Lizard	Snout - vent length	0	0
Frog	Snout - vent length	0	0
Freshwater fish	Standard length	96.3±6.0	58±8.8
Estuarine fish	Standard length	88.8±2.2	42.4±6.9

*Indicates a significant difference by *t test, P*<0.001

Table. 6.15 Comparison of the mean sizes of prey for Intermediate egret and little egret

Taxon	Dimension	Mean Prey size ± 95% CI (mm)	
		Intermediate egret	Little egret
Snake	Snout - vent length	0	0
Lizard	Snout - vent length	0	0
Frog	Snout - vent length	0	0
Freshwater fish	Standard length	58.6±0.5*	49.6±2.3*
Estuarine fish	Standard length	55.5±3.2*	57.7±2.3*

*Indicates a significant difference by *t test*, $P<0.001$

6.3.1 Impact on prey abundance

Numbers and distribution of prey animals (Pila globosa): Differences were detected between near the aquaculture farms and faraway aquaculture farms. In case of *Pila globosa* more individuals were caught far away from Aquaculture farms. The numbers were significantly greater in far away from the farms. Consistent significant differences were found in the numbers and biomass of *Pila globosa* between the categories (Table 6.16 and Table 6.17).

Table. 6.16 Number of *Pila globosa* (± SE; n=272), near and far away from aquaculture farms counted during sampling

Prey item	Near the farm	Faraway from farm	Statistic (Wilcoxon matched pairs test)
Pila globosa	0.07±0.005	2.88±2.225	$p<0.05$

Table. 6.17 Numbers and biomass (g dw) ± SE of *Pila globosa*; near and far away from aquaculture farms counted during sampling

Prey item	Numbers		Biomass	
Pila globosa	$F_{1.35}$	*p*	$F_{1.35}$	*p*
	16.15	0.001	14.16	0.001

6.4 Summary of findings

A total of 1422 regurgitated food boluses were collected and analyzed. Food items were segregated and identified to species level. Morphometry of the food items were also recorded to determine as how birds avoid competition by choosing same prey species but in different sizes. Food preference for different species were determined. All birds showed major preference to fish except, Asian Openbill which fed 99.7% exclusively on apple snails (*Pila globosa*). Crabs were majorly preferred by White ibis, little cormorant. White ibis had significant proportion of prawns and shrimps in the diet. Night heron showed evidence on predating / scavenging on birds (Little egrets were found on 17 regurgitated samples). Water snakes (*Enhydris enhydris* and dog faced water snake) were preferred by purple heron followed by Night heron, grey heron and little cormorant. Insects (Mostly water beetle larvae) were largely preferred by White ibis, Little cormorant, Intermediate egret and little egret. Aquaculture farms are on a raise for the past one decade after the blue revolution all along the Indian coastal belts. Bhitarkanika is no exception and our surveys around the Bhitarkanika National Park and inside Bhitarkanika wildlife sanctuary revealed more than 672 farms dotting the periphery of the park. Direct evidence of intake and release of saline water from and to the river systems could have an impact on the fish population which is the major prey base for the nesting birds in the heronry. Food abundance was low adjoining the aquaculture farms thereby affecting the abundance of the forage base for Asian Openbill storks.

Plate no. 11 Most of the birds from the nesting colony are commonly seen foraging in the paddy fields adjoining the Sanctuary (personal observation). In recent years paddy fields in this area are rapidly being converted to shrimp ponds, thus reducing the foraging areas available for the breeding birds. (Photo © Gopi.G.V)

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